NORTHROP

PARACHUTE SUBSYSTEM
APOLLO BLOCK II
INCREASED CAPABILITY
EARTH LANDING SYSTEM
FINAL REPORT OF THE SERIES
QUALIFICATION DROP TESTS

VOLUME I

NVR-6070 A

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PARACHUTE SUBSYSTEM
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INCREASED CAPABILITY
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FINAL REPORT OF THE SERIES 85
QUALIFICATION DROP TESTS

Prepared for:
Space Division of
North American Rockwell Corporation
Under Purchase Order M7J7XAZ-470004A

Prepared by:
H. L. Murray
Field Test Branch

NOTE: Pages of this report revised since the original issue have been marked with the change letter after the report number.

Approved by:

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FOREWORD

This report was prepared in compliance with Paragraph 3.3.1.3 of NR Specification MC-999-0085A, "Documentation for Apollo Major Subcontractors," which imposes the requirement for a final report covering the qualification aerial drop tests of the Apollo Block II Earth Landing System, Increased Capability Program. This activity was accomplished under the authority and requirements of Purchase Order M7J7XAZ-470004A, wherein Northrop Ventura is responsible to North American Rockwell and the National Aeronautics and Space Administration, MSC (Prime Contract No. NAS 9-150) for the design, development, qualification, fabrication, and delivery of the Apollo Block II, Increased Capability Parachute Subsystem.

This report concerns only the Series 85 Qualification Drop Tests of the system development and qualification tests conducted by Northrop Ventura and represents the final portion of the total effort on the Apollo Block II Increased Capability Parachute Subsystem. Seven aerial drop tests were conducted at the Department of Defense Joint Parachute Test Facility, USNAF, El Centro, California, and utilized Boilerplate-6C as the test vehicle.

The USAF 6511th Test Group (Parachute) furnished all operational, administrative scheduling, and range support at El Centro. Photographic and shop facilities support was provided by the US Naval Parachute Facility. McDonnell Douglas Corporation, Long Beach, California, maintained and operated the NASA supplied C-133A launch aircraft, and was also responsible for loading the test vehicle into the cargo compartment. Photo chase aircraft support was provided by the USAF 6511th Test Group.

Assistance in preparation of this report was rendered by the Apollo Project Office and various engineers in the Northrop Ventura design, analysis, and reliability organizations.

This report emphasizes the qualification of the Block II Increased Capability Parachute Subsystem on the system level by means of the aerial drop test program. Some components and assemblies were qualified during laboratory tests, and their qualification was further enhanced through successful performance during the aerial drop tests. Hence, these items are treated on a subordinate level with respect to the scope of this report. Justification for qualification during laboratory tests and by similarity is indicated in Section 2.0 for those items qualified in the Block I or earlier Block II programs which experienced only minor changes. The continuing qualification status of items which did not change during the earlier Block I and Block II programs is cited. Thus all specification requirements for qualification are incorporated within the scope of this report.

For purposes of clarity and ease of handling, the report has been divided into two volumes. Volume I contains the basics of the program while Volume II contains supporting information.

VOLUME I

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SECTION 1.0

INTRODUCTION

Over a period of approximately three months commencing on 4 April 1968 and ending on 3 July 1968, a total of seven Parachute Subsystem qualification aerial drop tests were conducted by Northrop Ventura on the drop test range of the Department of Defense Joint Parachute Test Facility, USNAF, El Centro, California. The boilerplate test vehicle was utilized to simulate the Apollo Command Module at a recoverable weight of approximately 13,000 pounds, and was air-dropped from a modified Douglas C-133A carrier aircraft at various test conditions designed to simulate the following test cases, which are also summarized in Table 1-1.

a. Two pad abort simulations with one bypassing both drogue parachutes, and one with apex cover and one without.

b. Two high altitude abort simulations without apex cover and utilizing only one drogue parachute. One test utilized only two main parachutes.

c. Three normal entry simulations, all with apex cover and two with only one drogue parachute.

The Parachute Subsystem configuration used throughout the qualification test program was of qualifiable status and representative of that utilized in spacecraft production design. The tests were conducted in accordance with the requirements of NVR-5091D, "General Test Plan, Apollo Block II, ELS, Increased Capability Program."

1.1 PARACHUTE SUBSYSTEM PERFORMANCE VERSUS TEST REQUIREMENTS

The performance requirements of the Increased Capability Parachute Subsystem are set forth in NR Specification ME 623-0006 (Ref. 1). These include assigned aerodynamic envelopes, maximum final rate of descent,

Table 1-1. Test Condition Configuration

Test No.	Fwd. Heat Shield	No. Drogue	No. Mains	Mission Simulation
85-1	Yes	2	3	Normal Entry
85-2	Yes	2	3	Pad Abort
85-3	Yes	1	3	Normal Entry
85-4	Yes	1	3	Normal Entry
85-5	No	1	3	High Alt. Abort
85-6	No	0	3	Pad Abort
85-7	No	1	2	High Alt. Abort

interface loadings to the spacecraft, dimensional envelope and weight limits, and environmental requirements. The requirements for demonstrating design specifications on the component level as applicable in the drop test program are outlined in the work statement of NR Purchase Order M7J7XAZ-470004A. Thus, the Northrop Ventura Block II Increased Capability Qualification Program consisted of both laboratory tests and aerial drop tests. The drogue mortar assembly, six- and ten-second reefing line cutters, and the pilot pressure cartridge were all qualified on the assembly or component level in laboratory tests while the complete Parachute Subsystem was qualified during the qualification aerial drop tests. In addition, the forward heat shield mortar assembly was designed to the specifications set forth in ME 623-0005, qualified during laboratory tests, and successfully demonstrated in four of the qualification drop tests.

Since only an actual operational mission could expose the system to full mission and environmental exposure, the qualification test series can only demonstrate the Parachute Subsystem against general performance requirements. This presents the following two characteristics:

a. The qualification test series is capable of accomplishing practical simulations of actual missions to produce rate of descent data and deployment/deceleration performance characteristics, during various dynamic conditions and vehicle body rates.

b. The series is capable of accomplishing the test requirements specified in work statement M7J7XAZ-470004A. The distinction between the act of performing successful mission simulation tests, and the resultant yield from the tests with respect to providing Parachute Subsystem qualification confidence, becomes meaningful when assessing the test objectives against specified performance requirements.

1.2 TEST OBJECTIVES

The primary objective of the Series 85 Qualification Tests was to verify Parachute Subsystem performance during aerial drop tests. The complete Parachute Subsystem was tested utilizing a full-scale boilerplate test vehicle. The Parachute Subsystem includes, but is not limited to, the drogue parachute mortar assemblies, the pilot parachute mortar assemblies, and the main parachute pack assemblies. The specific test objectives were as follows:

a. Verification of Parachute Subsystem performance during normal entry simulations and simulated pad and high aborts.

b. Verification of drogue parachute performance behind the boilerplate and determination of the drogue parachute X-factor (opening shock factor) ratio of actual maximum load to the steady state load at the same dynamic pressure, and effective drag area ($C_D S$).

c. Determination of the stability of the combined boilerplate and drogue(s).

d. Final verification of the main parachute two-stage reefing system.

e. Final verification of reefed inflation load sharing characteristics.

f. Final verification of disreefed inflation load sharing characteristics.

g. Verification of the forward heat shield separation system.

1.3 GROUND RULES

In accordance with the general philosophy of qualification testing, applicable specifications, and other agreements, both mutual and contractual, the following ground rules were adopted and implemented throughout drop test operations.

a. Qualified or qualifiable Parachute Subsystem components and installation specifications would be used; hardware configurations would be compromised as little as possible by the addition of extraneous items such as load links or other instrumentation. No test would be knowingly allowed to proceed using a hardware configuration short of spacecraft design; deviations to this rule would be permissible only with the advance approval of NR. (No deviations were necessary, except for the strain link assembly added to the main parachute steel risers during the last three tests.)

b. All Parachute Subsystem test specimen hardware would be newly manufactured items with the single exception of the sequence controller which was specifically approved for reuse, but only after passing postflight checkout criteria.

c. A Flight Readiness Review (FRR) of each test would be conducted at the Northrop Ventura facility no later than two days prior to the planned test date. This engineering review would be chaired by NASA and would consist of a panel representing Northrop design, reliability, analytical, and project organizations, as well as counterpart personnel representing NR and NASA. The FRR provides the final approval for conducting the planned test and is summarized in the notes written during the meeting.

d. An engineering evaluation of each test would be conducted at the field site no later than the day following the test, and the evaluation summarized in meeting notes written during this evaluation. This engineering evaluation meeting would be chaired by the Northrop Ventura Project Engineer for Apollo Test, and would consist of a panel representing cognizant Northrop design, test, reliability, and project personnel, as well as counterpart personnel representing NR and NASA.

e. Each test would be conducted in accordance with a Northrop Ventura individual detailed field test plan with the prior approval of NR. Each test would be evaluated on a preliminary basis as indicated in item (c) above, and summarized in a special "Red Book" report to facilitate the rendering of Technical Review Board (TRB) preliminary approval to proceed with the subsequent test.

f. As soon as possible after completion of each test, on a date mutually agreeable, a joint NASA/NR Technical Review Board would assess the results of each test to the detail of each hardware discrepancy using as aids the test photo coverage, parachute damage charts, malfunction reports, and all available flight data. Final decisions as to the success or failure of a given test would rest with the Board. Following each given test, accomplishment of the next test would be by specific joint approval of the Board to proceed.

g. The criteria for classification as a successful drop test would be that, "The Parachute Subsystem; forward Heat Shield Mortar Assembly (if applicable); Drogue Parachute Mortar Assembly; Pilot Parachute Mortar Assembly; Pack Assembly - Main Parachute; major components, or parts are required to perform their function within the limits specified in MC 623-0006. Damage during deployment, of a minor nature, is acceptable, provided normal operation of each individual component is not impaired. If the Parachute Subsystem, or principal components and assemblies of the Parachute Subsystem fail, the test is not successful and a repeat of the test may be required subject to test review board negotiations."

h. At the close of the total test program, a final qualification report of the series would be prepared. The scope of the final series report would be restricted to the Parachute Subsystem. Thus, pertinent information on the performance of other parts of the ELS such as location aids, uprighting gear, apex cover ejection, main and drogue parachute disconnect, etc., would not be documented in detail, but only to the extent that such performance might affect operation of the Parachute Subsystem. (The individual flight test reports, postflight engineering evaluation conference notes, and TRB books would cover the relevant area of interest.)

Other specific ground rules covering the operational aspects of the program such as test changes, flight scheduling, and test specimen disposition are covered in detail in Northrop Ventura Report No. 3876B, "Field Test Operations Plan, Apollo Block II Earth Landing System, Increased Capability Program." This document was coordinated with cognizant NR and NASA engineering and quality assurance representatives prior to implementation.

SECTION 2.0

PARACHUTE SUBSYSTEM CONFIGURATION

This section contains a description of the principal elements of the Apollo Block II Increased Capability Parachute Subsystem test specimens used during the qualification drop-test program. A brief comparison of configuration differences between these items and earlier qualified Block II components is also presented. The qualified Block II system is taken to be the S/C 101 configuration prior to Increased Capability. Where applicable, the basis for qualification by similarity is developed for certain Block II Increased Capability components which have experienced only minor design modifications from their earlier Block II counterparts. Continued qualification status was granted to those items which did not change from the Block II configuration.

2.1 SUMMARY

Throughout the seven drop tests conducted in the Block II Increased Capability Qualification program, only minor configuration changes were made to the spacecraft configuration hardware being qualified and these were improvement modifications to provide a more reliable system. These changes are discussed in detail in the appropriate paragraphs of this section. Table 2-1 is a listing of the major component configurations (at the Northrop Ventura drawing level) used on each of the seven drop tests and the corresponding configurations for S/C 101 (developed to NR Specification ME623-0006). These configurations are hereby declared to be the final Block II Increased Capability spacecraft man-rated production designs.

The major assemblies of the Apollo Block II Increased Capability Parachute Subsystem, as defined by NR Specification ME 623-0006, are listed in Table 2-2.

Details of the various assemblies are illustrated in Figures 2-1 through 2-5.

TEST VEHICLE DETAILS		TEST NUMBER AND DATE	
ASSEMBLY AND REFERENCE	COMPONENT ASSEMBLIES OF TEST VEHICLES		
	NV NO.	85-1 QDT-1	85-3 QDT-2
	GENERAL ASSEMBLY	PDS 5839-1	PDS 5839-5
	DATE	4/4/68	4/24/68
	BOILERPLATE	B/P-6C	B/P-6C
DROGUE PARACHUTE MORTAR ASSEMBLY (PAR. 2.2)	ASSEMBLY	R8110-5	R8110-5①
	DROGUE PARACHUTE PACK ASSEMBLY	R8157-515	R8157-515
	DEPLOYMENT BAG	R8156-501	R8156-501
	PARACHUTE	R8155-509	R8155-509
	REEFING LINE CUTTERS	58517-10	58517-10
	MORTAR TUBE ASSEMBLY	R8107-1	R8107-1
PILOT PARACHUTE MORTAR ASSEMBLY (PAR. 2.3)	ASSEMBLY	R8040-9	R8040-9
	PILOT PARACHUTE PACK ASSEMBLY	R7515-507	R7515-507
	DEPLOYMENT BAG	R7514-507	R7514-507
	PARACHUTE	R7516-505	R7516-505
	MORTAR TUBE ASSEMBLY	R8041-5	R8041-5
MAIN PARACHUTE PACK ASSEMBLY (PAR. 2.4)	PACK ASSEMBLY	R8058-503	R8058-503
	PARACHUTE ASSEMBLY	R7541-551	R7541-551
	83.5 Do RINGSAIL PARACHUTE	R7661-519	R7661-519
	DEPLOYMENT BAG	R8080-503	R8080-503
	REEFING LINE CUTTERS 6 SECOND	58516-6	58516-6
	10 SECONDS	58517-10	58517-7
MAIN PARACHUTE RETENTION ASSEMBLY (PAR. 2.5)	+Y BAY, -Y BAY	R8091-1	R8091-1
	+Z BAY	R8091-3	R8091-3
M/C STEEL RISER (PAR. 2.6)	MAIN PARACHUTE RISER ASSEMBLY	R8030-5	R8030-5
CARTRIDGES (PAR. 2.7, 2.8)	PILOT CARTRIDGE	58503-13	58503-13
	DROGUE CARTRIDGE	58502-11	58502-11
SEQUENCE CONTROLLER (PAR. 2.9)	SEQUENCE CONTROLLER⑥	R6920-517	R6920-517
FWD HEATSHIELD MORTAR ASSEMBLY (PAR 2.11)	ASSEMBLY	R8130-5	R8130-5
	PACK ASSEMBLY	R8159-501	R8159-501
	DEPLOYMENT BAG	R8158-1	R8158-1
	PARACHUTE ASSEMBLY	R7516-507	R7516-507
FOLD-OUT #1	MORTAR TUBE ASSEMBLY	R8131-1	R8131-1

* DENOTES CONFIGURATION CHANGE

① DROGUE MORTAR ASSEMBLY, R8110-11, USED FOR BACKUP DROGUE PARACHUTE

② TWO DROGUE MORTAR ASSEMBLIES, DR 8110-19, USED FOR BALLAST ONLY

③ THESE MAIN PARACHUTE STEEL RISERS WERE MODIFIED WITH STRAIN LINKS TO PROVIDE LOAD MEA

④ ONE PILOT MORTAR ASSEMBLY, DR 8040-5, USED FOR BALLAST ONLY

⑤ ONE MAIN PARACHUTE PACK ASSEMBLY, DR 8058-539, USED FOR BALLAST ONLY

⑥ QUALIFIED DURING BLOCK I QUALIFICATION TESTS (SEE TER-818). SEQUENCE CONTROLLERS USED

85-2 QDT-3	85-6 QDT-4	85-5 QDT-5	85-4 QDT-6	85-7 QDT-7	S/C 101
PDS 5839-3	PDS 5839-11	PDS 5839-9	PDS 5839-7	PDS 5839-13	R 8000-5
5/1/68	5/14/68	6/6/68	6/17/68	7/3/68	------
B/P-6C	B/P-6C	B/P-6C	B/P-6C	B/P-6C	------
R8110-5 R8157-515 R8156-501 R8155-509 58517-10 R8107-1	DR8110-19② DR8157-511 R8156-501 R8155-509 58517-10 R8107-1	R8110-5 ① R8157-515 R8156-501 R8155-509 58517-10 R8107-1	R8110-5 ① R8157-515 R8156-501 R8155-509 58517-10 R8107-1	R8110-5 ① R8157-515 R8156-501 R8155-509 58517-10 R8107-1	R8110-1 R8157-511 R8156-501 R8155-509 58517-10 R8107-1
R8040-9 R7515-507 R7514-507 R7516-505 R8041-5	R8040-11* R7515-509* R7514-507 R7516-509* R8041-5	R8040-11 R7515-509 R7514-507 R7516-509 R8041-5	R8040-11 R7515-509 R7514-507 R7516-509 R8041-5	R8040-11④ R7515-509 R7514-507 R7516-509 R8041-5	R8040-11 R7515-509 R7514-507 R7516-509 R8041-5
R8058-503 R7541-551 R7661-519 R8080-503 58516-6 58517-10	R8058-503 R7541-551 R7661-519 R8080-503 58516-6 58517-10	R8058-503 R7541-551 R7661-519 R8080-503 58516-6 58517-10	R8058-503 R7541-551 R7661-519 R8080-503 58516-6 58517-10	R8058-503⑤ R7541-551 R7661-519 R8080-503 58516-6 58517-10	R8058-503 R7541-551 R7661-519 R8080-503 58516-6 58517-10
R8091-1 R8091-3	R8091-1 R8091-3	R8091-1 R8091-3	R8091-1 R8091-3	R8091-1 R8091-3	R8091-1 R8091-3
R8030-5	R8030-5	③ PDS 6020-1	③ PDS 6020-1	③ PDS 6020-1	R 8030-1
58503-13 58502-11	58503-13	58503-13 58502-11	58503-13 58502-11	58503-13 58502-11	58503-13 58502-11
R6920-517	R6920-517	R6920-517	R6920-517	R6920-517	R8204-1
R8130-5 R8159-501 R8158-1 R75616-507 R8131-1	NOT USED FOR THIS TEST	NOT USED FOR THIS TEST	R8130-5 R8159-501 R8158-1 R7516-507 R8131-1	NOT USED FOR THIS TEST	R8130-5 R8159-501 R8158-1 R7516-507 R8131-1

FOLD-OUT #2

SUREMENTS. THEY ARE SIMILAR TO SPACECRAFT CONFIGURATION

ARE QUALIFIED BY SIMILARITY

Table 2-1. Parachute Subsystem and Assembly Configuration

Figures 2-6 through 2-9 inclusive, illustrate typical rigging installation of the entire Parachute Subsystem in the respective bays of the forward compartment of Boilerplate-6C (see pages 2-22 through 2-25).

Table 2-2. Major Components of Apollo Block II Increased Capability Parachute Subsystem

Nomenclature	NR Number	NV Number
Parachute Subsystem	ME 623-0006-0001	R8000
Main Parachute Pack Assembly	ME 623-0007-0001	R8058-503
Drogue Parachute Mortar Assembly	ME 623-0008-0001	R8110-1
Pilot Parachute Mortar Assembly	ME 623-0001-0003	R8040-11
Main Parachute Riser Assembly	ME 901-0694-0001	R8030-1
Retention Assembly (-Y, +Y Bays)	ME 901-0693-0001	R8091-1
Retention Assembly (+Z Bay)	ME 901-0693-0002	R8091-3
Drogue Pressure Cartridge	ME 453-0005-0091	58502-11
Pilot Pressure Cartridge	ME 453-0005-0093	58503-13
*Mortar Assembly Forward Heat Shield	ME 623-0005-0002	R8130-5
*Sequence Controllers	ME 901-0001-0037	R8204-1

*Additional components of the Apollo Earth Landing System.

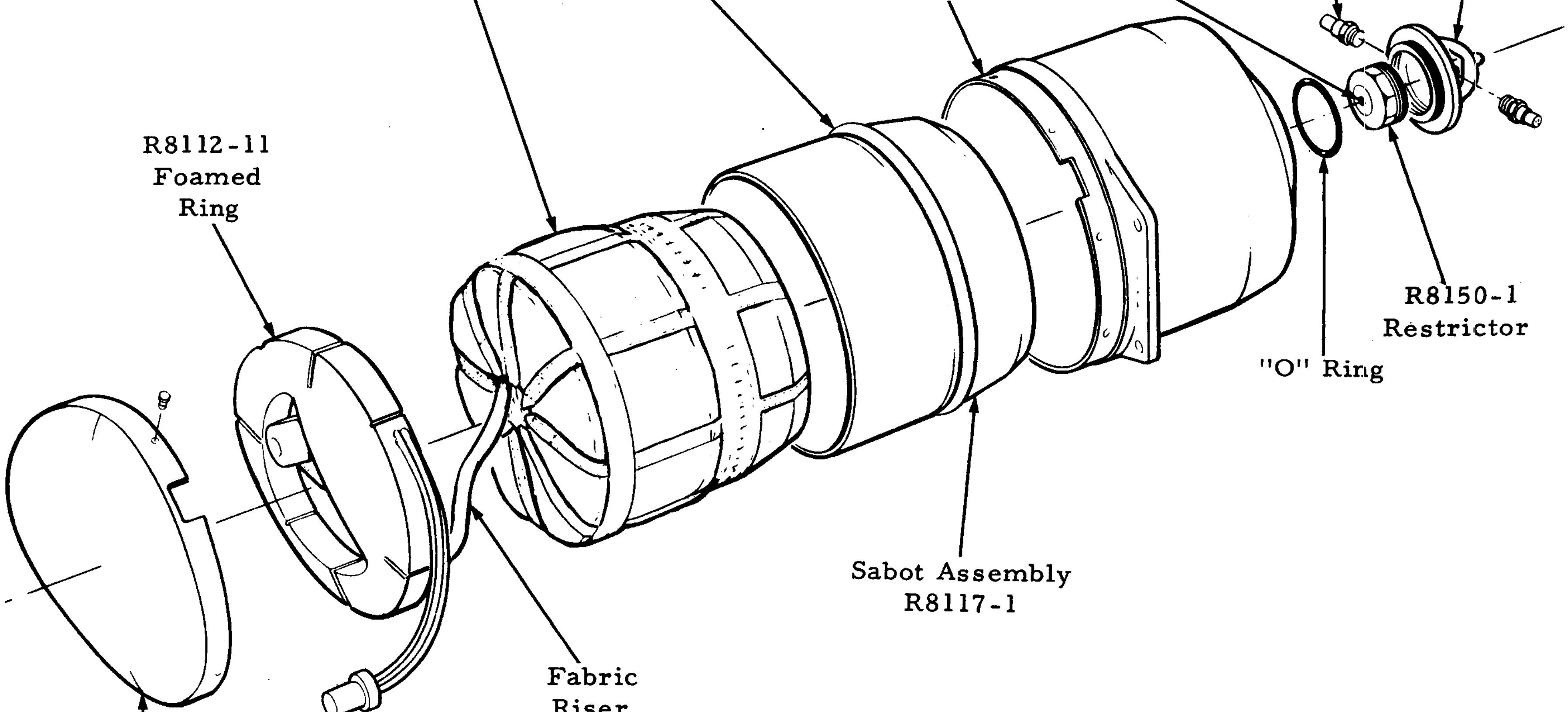
Table 2-3, found on page 2-27, is a one-page summary of the information contained in the text of this section. Block II and Block II Increased Capability counterpart configurations are listed, together with configuration variances, basis for qualification and the documentation necessary to attest the qualification.

2.2 DROGUE PARACHUTE MORTAR ASSEMBLY, R8110-1

Two identical R8110-1 Drogue Parachute Mortar Assemblies are used in each Parachute Subsystem to provide the means for deceleration and stabilization of the spacecraft to a velocity and attitude which will assure proper mortar deployment of the pilot parachutes and subsequent extraction and deployment of the main parachutes. Each mortar assembly ejects a R8157-515 Drogue Parachute Pack Assembly from the mortar tube into the airstream utilizing forces generated by controlled pyrotechnic gas pressure from the mortar breech. Two electrically initiated cartridges (see paragraph 2.7) are used to generate the necessary gas pressure. As the gas pressure increases in the mortar tube, the sabot compresses the parachute pack assembly against the mortar cover causing the retainer pins to be sheared and the release of the parachute pack assembly.

As the pack assembly travels towards line stretch, the steel riser is uncoiled from its foamed ring. When line stretch is attained, the deployment bag is stripped from the R8155-509 Drogue Parachute permitting parachute inflation and operation. The drogue parachute is a 16.5 ft nominal diameter (D_o) conical ribbon parachute and utilizes one stage of reefing. The drogue parachute is initially reefed to 42.8% D_o and uses redundant reefing lines with two ten-second (nominal) reefing line cutters on each line. A permanent reefing line is incorporated to prevent inflation beyond a 10.0 ft diameter after disreef.

One drogue mortar assembly is mounted on each side of the disconnect assembly in the -Z Bay of the forward compartment of the spacecraft. The pin on the breech end of the mortar assembly is inserted into the hole in the channel of the lower portion of the disconnect support structure. The drogue mortar mounting flange is bolted to the upper portion of the disconnect housing support structure utilizing two bolts. Electrical bonding is provided through mutually contacting "clean" areas on both the mortar and the mounting structure. The Drogue Parachute Mortar Assembly and the relationship of all component parts is illustrated in Figure 2-1.



Weight = 50.2 pounds
(Without Cartridges)

Figure . Drogue Parachute Mortar Assembly, R8110-1

The major difference between the Block II Increased Capability Mortar Assembly and the earlier Block II design was that the new mortar assembly was designed to deploy a larger drogue parachute and is thus larger and heavier. The diameter of the drogue parachute was increased from 13.7 feet to 16.5 feet and both the suspension lines and riser were strengthened. The suspension lines and fabric riser were constructed using twenty (20) 2500 pound strength nylon lines. The drogue parachute steel riser (R8109-9) was also increased in strength and utilized a four cable assembly with swaged end-fittings instead of the three cable assembly utilized for the earlier Block II design.

The R8110-5 Drogue Mortar Assembly was used during the Block II Increased Capability qualification drop test program and its configuration remained unchanged throughout the seven-test series. Also the mortar assembly utilized for the qualification drop test program is identical to the spacecraft configuration drogue mortar assembly (R8110-1)with the following exceptions:

a. The test specimen mortar assemblies contained spacecraft type steel risers with the addition of strain gage instrumentation to the clevis and two teflon coated instrumentation wires along the full length of the steel riser and intermittently taped to the riser cable.

b. The clevis assembly was modified to provide space for the strain gages and an aluminum plate was bonded over each side of the clevis to protect the strain gages.

The design performance and structural integrity of the newly designed Drogue Parachute Mortar Assembly were adequately demonstrated and qualified on the basis of successful performance during the seven-test qualification series and in the supplemental laboratory qualification tests.

2.3 PILOT PARACHUTE MORTAR ASSEMBLY, R8040-9, R8040-11

Three identical R8040-9 Pilot Parachute Mortar Assemblies (see Figure 2-2) are used to extract and deploy the three main parachutes.

Each mortar assembly ejects a R7515-507 Pack Assembly from the mortar tube into the airstream utilizing forces generated by controlled pyrotechnic gas pressure from the mortar breech. Two electrically-initiated cartridges (see paragraph 2.8) are used to generate the necessary gas pressure. As the gas pressure increases in the mortar tube, the sabot compresses the parachute pack assembly against the mortar cover causing the retainer pins to be sheared and the release of the parachute pack assembly. As the pack assembly travels towards line stretch the steel riser is uncoiled from its foamed ring. After line stretch, the pack assembly strips the R7514-507 Deployment Bag from the R7516-505 Pilot Parachute effecting its deployment.

The pilot parachute is a 7.2 ft D_o ringslot parachute permanently attached to the main parachute deployment bag through the steel riser. Both the pilot parachute and the main parachute deployment bag remain permanently attached to the apex of the main parachute.

The R8040-9 Pilot Parachute Mortar Assembly remained essentially unchanged from the earlier Block II design. The only changes to this assembly were modifications to strengthen the pilot parachute. The pilot parachute was modified from the -501 version by increasing the suspension line strength from 400 to 600 pounds and changing the fabric riser to an integrated suspension line-riser configuration. This design was designated as the R7516-505 Pilot Parachute.

The configuration of the R8040-9 Pilot Parachute Mortar Assembly remained basically unchanged through the qualification test program with the exception of a minor modification to the pilot parachute (R7516-505). During Drop Tests 85-2 and 85-3 the sleeve over the pilot parachute fabric riser broke loose from the clevis end of the riser and gathered towards the keeper. To

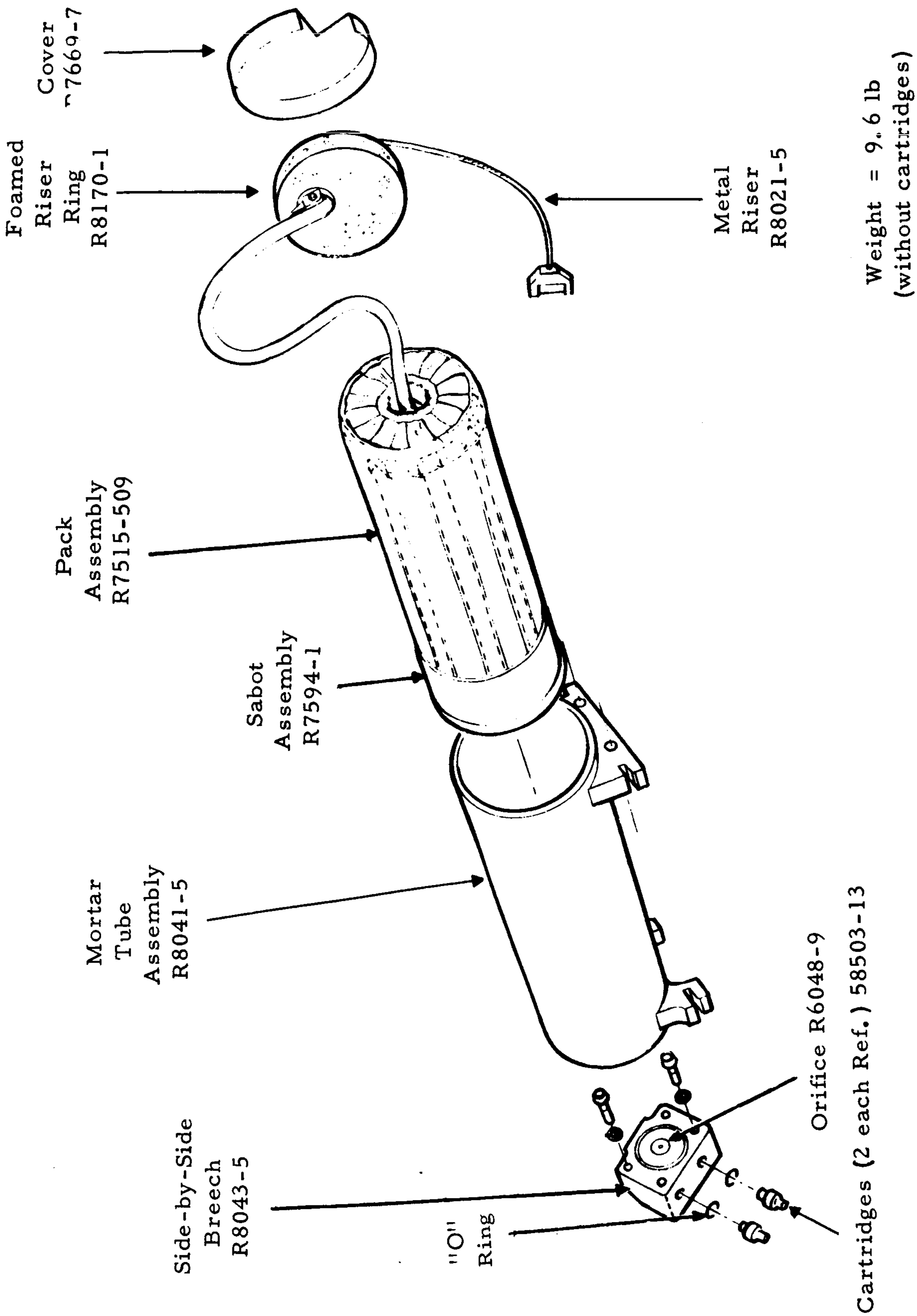


Figure 2-2. Pilot Parachute Mortar Assembly, R8040-11

prevent further occurrences, the length of the sleeve was increased and additional stitching was applied to the sleeve at the clevis end in order to strengthen its attachment. This change resulted in the R7516-509 configuration for the pilot parachute and the R7515-509 configuration for the pilot parachute pack assembly. The new mortar assembly configuration R8040-11 was incorporated in Drop Test 85-6 and remained unchanged throughout the remainder of the qualification test series.

The R8040-11 Pilot Parachute Mortar Assembly is judged to be acceptable for full qualification status, on the basis of successful performance demonstrations throughout the qualification drop test program (configuration remained unchanged during the last four tests), and on the basis of similarity to the earlier qualified Block II design.

2.4 MAIN PARACHUTE PACK ASSEMBLY, R8058-503

Three R8058-503 Main Parachute Pack Assemblies are used in the Parachute Subsystem for controlling the final rate of descent to within specification limits. The main parachute pack assembly consists of the subassemblies and items illustrated in Figure 2-3.

The main parachute (R7661-519) is a 83.5 ft D_o conical ringsail parachute actively reefed in two stages. The first stage is actively reefed to 8.4% D_o and utilizes redundant reefing lines with two 6.0 second (nominal) reefing line cutters on each line. The second stage is actively reefed to 24.8% D_o and utilizes two 10.0 second (nominal) reefing line cutters on a single reefing line. The parachute assemblies are retained within their respective deployment bags and stored in the forward compartment of the vehicle. The packs are held in place by the parachute retention system (see paragraph 2.5).

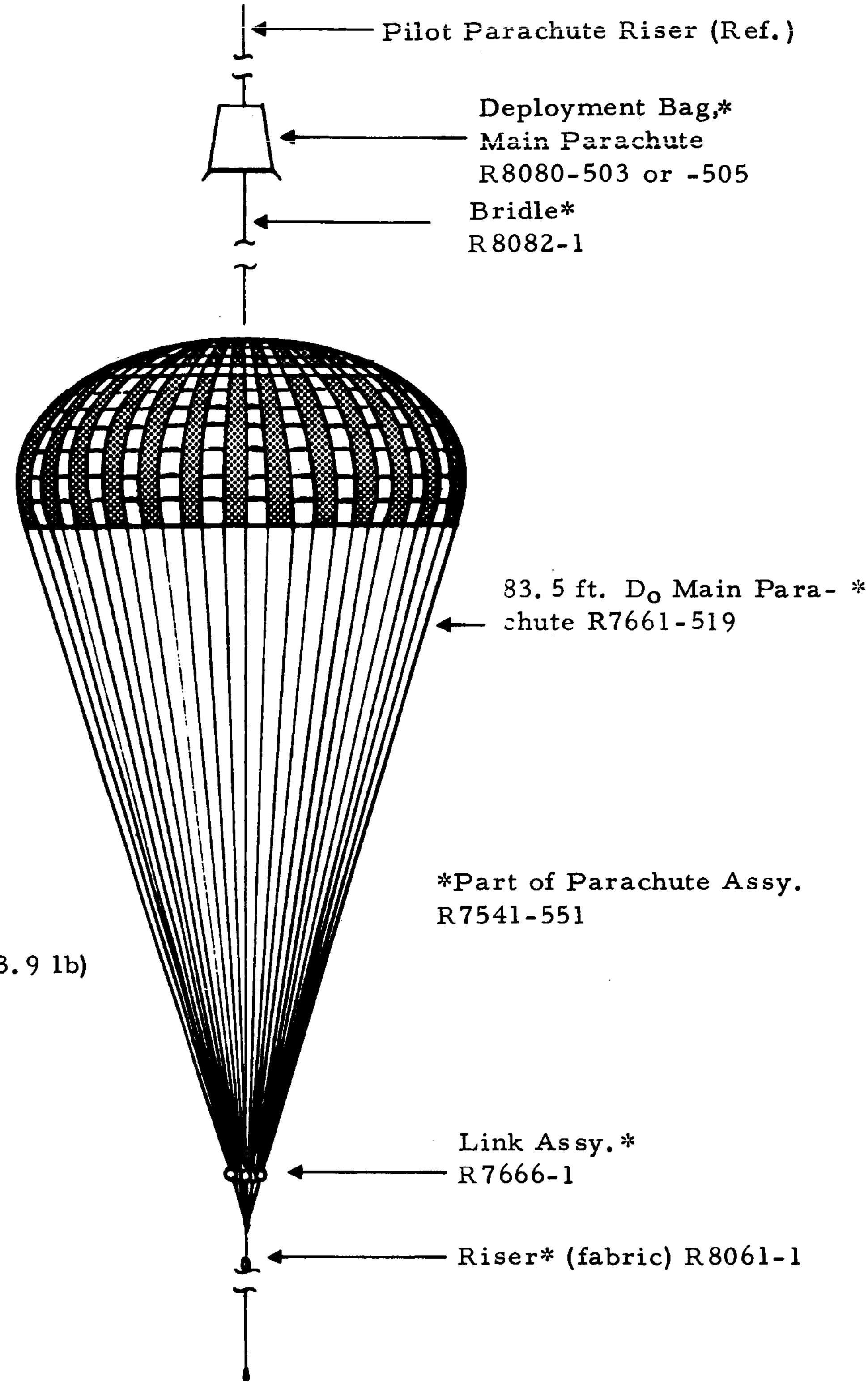


Figure 2-3. Components, Main Parachute Pack Assembly, R8058-503 and -505

As an individual component of the Parachute Subsystem, the R8058-503 Main Parachute Pack Assembly, including retention provisions, remained unchanged throughout the qualification drop test program and has achieved full qualification status on the basis of successful performance during all seven tests. That portion of the assembly which did not experience change from the earlier Block II configuration is also considered qualified by the evidence of similarity.

The R8058-503 Main Parachute Pack Assembly utilized for the Block II Increased Capability Program is similar to the earlier Block II design with the exception of the incorporation of two-stage reefing in the main parachute canopy and minor structural modifications to the deployment bag. The two-stage reefing system was required to maintain load limits on the 83.5 ft D_o main parachutes and the Apollo command module structure within the design limits. Reinforcement webbing was added to the flap attachment points, and a tie loop structure was added to strengthen the side lacing of the R8080-501 Deployment Bag. This strengthened deployment bag configuration was designated R8080-503. The R8080-503 Deployment Bag is the production version of the -503 bag and is interchangeable with it.

The development of the main parachute two-stage reefing system took place during the Series 80 and 81 Development tests (see Ref. 23). The structural capability of the R8080-503 Deployment Bag and the R7661-519 Main Parachute utilizing two-stage reefing was adequately proven in the Series 82 Tests (see Ref. 24) utilizing the ICTV. Supplementary laboratory development tests included pack extraction tests, and various other component tests add to the level of confidence in the performance of this assembly.

Successful stowage of a total of 20 pack assemblies into Boilerplate 6C qualifies the as-delivered configuration with respect to specification envelope, and packing and rigging techniques.

2.5 MAIN PARACHUTE RETENTION ASSEMBLIES, R8091-1 AND R8091-3

The R8091-1 and -3 Main Parachute Retention Assemblies are designed to perform two discrete functions: to retain the main parachute pack assemblies in the forward compartment of the spacecraft and within the specified installation envelope; and to provide for unrestrained and positive release of the packs during extraction. Each retention assembly consists of a series of fabric covered steel spring straps, chain-laced to loops on the face of the main parachute deployment bag by means of an interlocking and continuous length of cord. The upper and lower chain lace rows are independent of each other, and each row is locked by a separate release pin. Both pins attach to a common lanyard assembly which in turn is attached to the clevis end-fitting of the pilot parachute steel riser. The retention assemblies are illustrated in Figure 2-4. Operation of the pilot parachute provides the force required to disengage the release pins and permit opening of the chain lace rows. The unlacing is augmented by the spring-back characteristics of the individual retention straps. The R8091-1 Retention Assemblies are identical and are located in the +Y and -Y bays of the forward compartment. The R8091-3 Retention Assembly is located on the +Z bay and differs from the -1 version in that one less strap is used on the upper row because of differences in the bays of the forward compartment.

The retention assemblies are exactly the same as the earlier Block II design. During the earlier Block II development tests the retention assemblies functioned numerous times during both ground and aerial drop tests. These tests featured extraction of the main parachute packs from simulated spacecraft bays at various pull-off angles during static ground tests, and successful deployment during the earlier Block II qualification tests (Series 73) using a boilerplate. During the Apollo Block II Increased Capability Program the retention assemblies were successfully demonstrated using the PTV in the

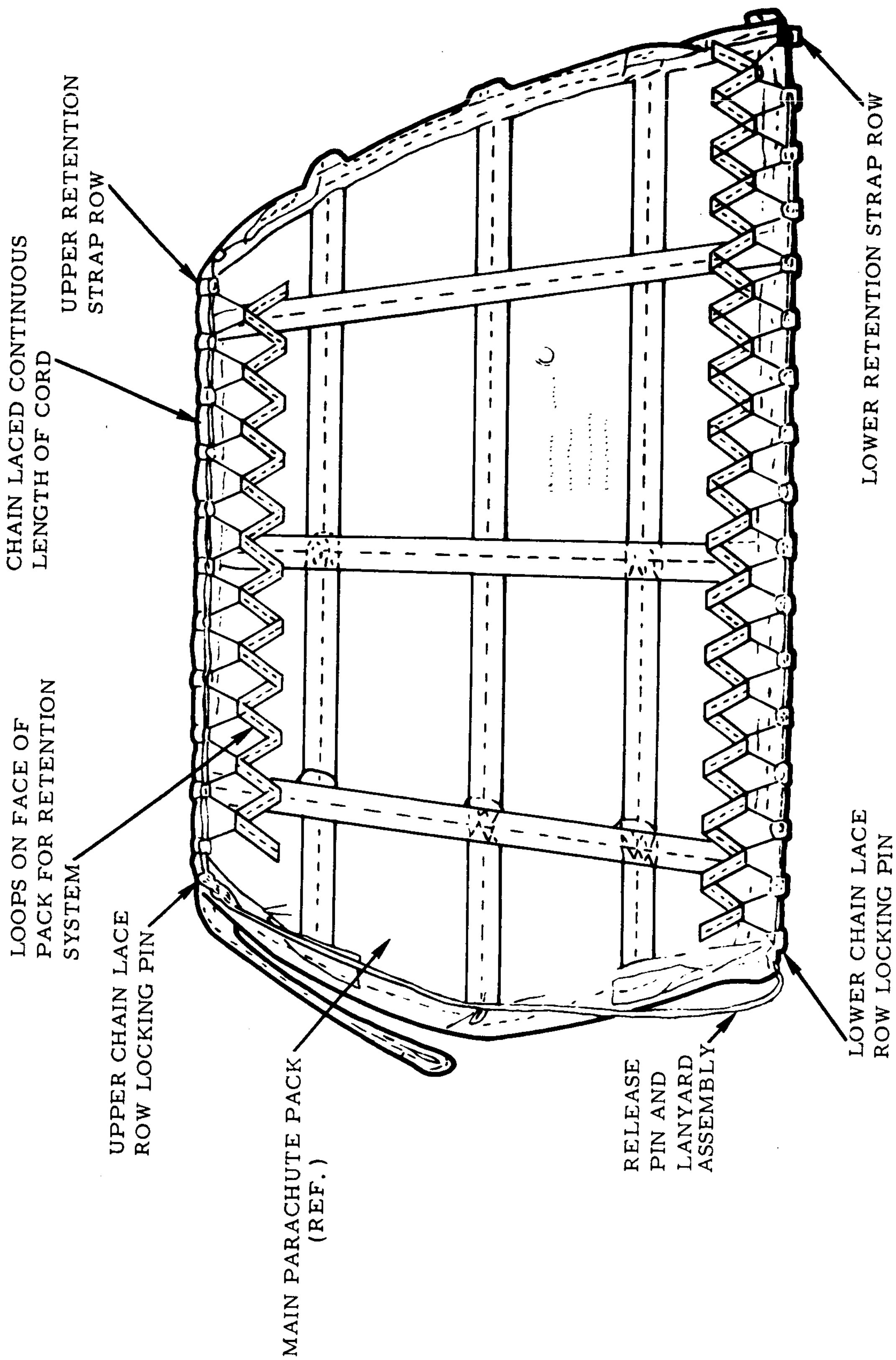


Figure 2-4. Main Parachute Retention Assembly R8091-1 and -3

Series 84 Tests, Test 83-6, and during all seven tests of the Series 85 Qualification Tests. The R8091-1 and -3 Retention Assemblies are considered to be acceptable for continued qualification status on the basis of successful performance during the qualification test program and on the basis of being identical to the earlier Block II design.

2.6 MAIN PARACHUTE RISER ASSEMBLY, R8030-1

The main parachute steel risers connect the main parachutes to the spacecraft and transmit the main parachute loads to the spacecraft following entry from terrestrial orbit, lunar flight, or mission abort conditions. Each individual riser is a six-cable assembly with swaged steel terminals designed for compatible attachment to the main parachute fabric riser on one end and to the NR-supplied spacecraft structure (main parachute disconnect mechanism) on the other.

Except for the end fittings, the assembly is encased in a Thermofit sleeve to maintain parallel positioning of the six individual wire cables relative to each other when in either the stowed or deployed positions.

These risers have the same configuration as those used in the earlier Block II design. Laboratory development tests demonstrated adequate margins of safety under the most severe conditions of bending and abrasion; and the functional performance of the steel riser was successfully demonstrated during developmental and qualification aerial drop tests, Series 70 and Series 73, respectively.

The main parachute risers (P/NR8030-5) used for the qualification drop tests were identical to those designed for spacecraft usage except for the added instrumentation. For the first four tests, strain gages were added to the riser clevis fitting and two teflon-coated instrumentation wires were run the full length of the cable, intermittently taped to the cable. Felt pads were bonded to each side of the clevis to protect the strain gages.

The load data obtained from the instrumented main parachute risers proved to be unreliable. The risers were modified for the last three tests by the addition of a strain link at the upper end of the riser between the clevis fitting and the riser cable. This modified riser was designated PDS 6020-1.

The R8030-1 Main Parachute Riser Assembly is considered acceptable for continued qualification status on the basis of performance throughout the development and qualification phases of the Apollo Block II Increased Capability Program and on the basis of being identical to the earlier Block II design.

2.7 DROGUE PRESSURE CARTRIDGE, 58502-11

The function of the drogue pressure cartridge is to provide optimum pressure levels within the drogue mortar breech and mortar tube for efficient and positive ejection of the drogue parachute pack assembly. The cartridge assembly performs its design function on electrical initiation (which can occur sympathetically). These cartridges incorporate a single bridgewire initiator, NASA Part No. SEB 26100001-216 and the cartridge body metal is Inconel 718. Four cartridges are required for each spacecraft mission, two in each drogue parachute mortar assembly.

These cartridges are identical to those qualified during the earlier Block II development and qualification tests and therefore retain their qualification status. Operation of these cartridges is further enhanced by successful use throughout both development and qualification tests of the Apollo Block II Increased Capability Program.

2.8 PILOT PRESSURE CARTRIDGE, 58503-13

The text relating to the drogue pressure cartridge (paragraph 2.7) applies as well to the pilot pressure cartridge inasmuch as both cartridges are utilized for providing gas pressure within a mortar breech. The cartridges are similar to the previously qualified design with the exception of the initiator, and the cartridge body metal is Inconel 718.

A total of eight (8) pressure cartridges is used for each spacecraft mission, and a similar quantity was used during the qualification drop tests. Two cartridges are used in each pilot mortar assembly and two are used in the forward heat shield mortar assembly.

The basis for qualification of these cartridges was their successful functioning during the laboratory qualification tests. Qualification status was further enhanced by the successful performance of the additional cartridges used during the Block II Increased Capability qualification drop test effort.

2.9 SEQUENCE CONTROLLER, R6920-517

The principal components of R6920-517 Sequence Controller are baroswitches, time delays, and relays. These components are connected in series/parallel configuration to eliminate single point failure modes. Two sequence controllers are required for each system and they are connected in parallel. This feature allows both units connected in parallel, or either unit individually, to provide the sequencing for controlling the deployment of the earth landing system. The sequence controller is not part of the Block II Increased Capability Program, and is considered auxiliary equipment.

The function of the sequence controller is to initiate individual functions of the ELS Parachute Subsystem and to provide signals indicating events occurrence. The sequence controllers logic bus and the 25,000 ft baroswitches are armed by the NR mission sequencer at an altitude between 100,000 and 50,000 feet. As the vehicle descends the baroswitches close at 25,000 $\pm$ 1000 feet and provide the following simultaneous functions:

a. Logic signal to the NR Mission Sequencer
b. Arm two-second time delays
c. Signal to indicate events occurrence through telemetry and hard line monitor.

Following a time interval of 0.4 seconds the mission sequencer will eject the forward heat shield of the vehicle and arm the sequence controller pyro power bus. After the two-second time delays function, a signal is provided to initiate drogue mortar fire. Also a signal to indicate occurrence of this event is sent through telemetry and hard line monitors.

The functioning of the 25,000 ft baroswitches also initiates a second circuit incorporating 14-second time delays. After run-out of these time delays, the low altitude baroswitches are armed. As the spacecraft descends through 10,750 ± 750 feet, these baroswitches actuate and provide the following functions and signals to indicate their occurrence:

a. Start fuel dump timers

b. Drogue parachute release

c. Pyro functions to initiate the pilot mortars

d. Power to arm the manual switch for main parachute disconnect

e. Provide signals to indicate events occurrence.

The automatic sequence described above can be overridden by the command pilot to by-pass drogue initiation or to lengthen the drogue parachute operating interval.

The R6920-517 Sequence Controller was fully qualified in the Block I program (see Ref. 8), and since no configuration changes were made during either the Block II or Block II Increased Capability Programs the prior qualification status is still retained. The successful performance of the sequence controller throughout the Block II Increased Capability test program enhances the reliability and confidence levels previously established. The R6920-517 Sequence Controller is exactly the same as the R8204-1 unit (which has a metallic coating and is designated for spacecraft usage). For additional information on the sequence controller and the other electrical equipment used during the qualification test program, see Appendix C.

2.10 REEFING LINE CUTTERS

2.10.1 Reefing Line Cutter, 58516-6

The 58516-6 Reefing Line Cutter is used in the main parachute to provide the first-stage disreef function at six (6) seconds (nominal) after full line stretch. The pyrotechnic time delay train is initiated when the spring loaded firing pin strikes a primer charge after the sear pin is extracted by the short-rigged suspension line lanyard tie. At burn-out of the time delay, a charge is ignited and generates the pressure which drives a knife blade through the reefing line, completing the function of the cutter.

A total of twelve (12) reefing line cutters (58516-6) are utilized for each spacecraft mission, and a similar quantity was used on each of the qualification drop tests. Four cutters are employed on each main parachute, two on each of the redundant first-stage reefing lines.

The 58516-6 Reefing Line Cutters were incorporated into the main parachute as a result of the Series 80 and 81 Development Tests which determined an optimum first-stage reefing interval of six (6) seconds. The basis for qualification of these reefing line cutters was their successful performance during laboratory qualification tests. Qualification status was further enhanced by the successful functioning of an additional 80 cutters during the Block II Increased Capability qualification drop test effort, plus others in the development test phase.

The 58516 Reefing Line Cutters are identical to the spacecraft versions except the spacecraft cutters have additional smoothing and blending of the radii on the sear adapter. These cutters were reidentified as 58516-60.

2.10.2 Reefing Line Cutter, 58517-10

The 58517-10 Reefing Line Cutter is utilized to provide the drogue parachute disreef function and the main parachute second-stage disreef function at ten (10) seconds (nominal) after full line stretch of the respective parachute. The functional operation of these cutters is the same as mentioned for the reefing line cutters in paragraph 2.10.1.

A total of fourteen (14) reefing line cutters (58517-10) is used for each spacecraft mission, and a similar quantity was used for each of the qualification drop tests. Four cutters are employed on each drogue parachute, two on each of the redundant reefing lines; and two cutters are employed in each main parachute on the second-stage reefing line.

The 58517-10 Reefing Line Cutters were incorporated into the main parachute as a result of the Series 80 and 81 Tests which established an optimum second-stage reefing interval of ten (10) seconds. These cutters were incorporated into the drogue parachute as a result of NR direction and were first utilized in Development Drop Test 99-5. The basis for qualification of these reefing line cutters was their successful performance during laboratory qualification tests. Qualification status was further enhanced by the successful functioning of an additional 72 cutters during the Block II Increased Capability qualification drop test effort, plus additional ones during the development test phase.

The 58517-10 Reefing Line Cutters are identical to the spacecraft versions except the spacecraft cutters have additional smoothing and blending of the radii on the sear adapter. These cutters were redesignated as 58517-100.

2.10.3 Reefing Line Cutter, 58558-8

These reefing line cutters operate in the same manner as the previously mentioned cutters. The cutters have the same configuration qualified during the Block I and Block II programs and therefore retain their qualification status for the Block II Increased Capability Program on the basis of being identical to the earlier configuration. Six (6) reefing line cutters 58558-8 are used to deploy the NR supplied location aids: the VHF antennas and the blinking light assembly.

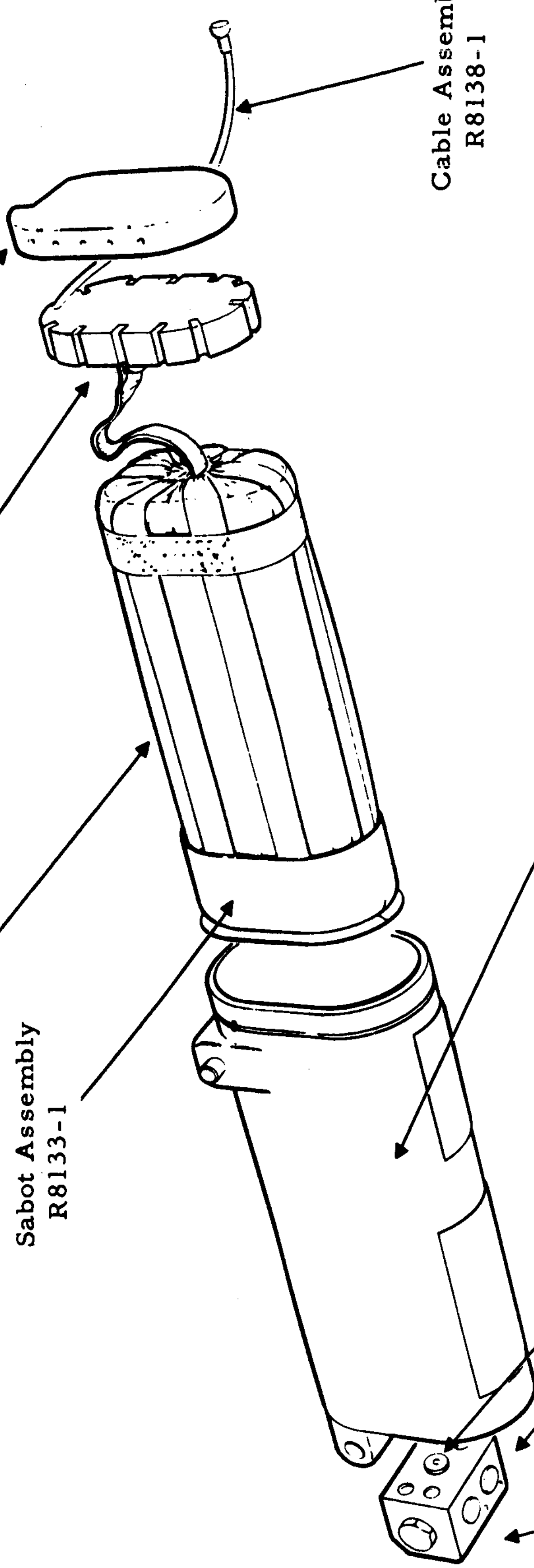
2.11 FORWARD HEAT SHIELD MORTAR ASSEMBLY, R8130-5

The forward heat shield mortar assembly (R8130-5) is utilized to augment the forward heat shield after its separation from the boilerplate.

Following separation of the forward heat shield and after a suitable time interval to permit clearance of the pack over the airlock rim, the forward heat shield mortar assembly is fired. The forward heat shield parachute pack assembly is guided through the opening in the top of the forward heat shield by a ramp. The forward heat shield mortar assembly and components are illustrated in Figure 2-5. Deployment of the parachute retards the forward heat shield and prevents it from contacting either the boilerplate or the components of the Parachute Subsystem. This sytem was not utilized on the earlier Block II configuration. The R8130-5 Forward Heat Shield Mortar Assembly was granted full qualification status on the basis of successful performance during Northrop Ventura conducted laboratory qualification tests. Qualification status was further enhanced by successful performance in the qualification drop test program during Qualification Drop Tests 85-1, 85-2, 85-3, and 85-4.

2.12 PARACHUTE SUBSYSTEM INSTALLATION

Installation and rigging of the Parachute Subsystem components into the respective bays of the boilerplate forward compartment was accomplished in accordance with NVR-6050B, "Boilerplate Test Vehicle, Installation and Rigging Instructions, AELS Test Program." Figures 2-6 through 2-9 illustrate typical configuration of the individual bays of the forward compartment of Boilerplate-6C. The installations shown are representative of spacecraft configuration with the exception of the instrumentation wiring and lanyards shown in Figure 2-6. The rigging and installation procedures used in the Block II Increased Capability Program are listed in Section 7.0



Weight = 10.2 lbs
(without cartridges)

Figure 2-5. Forward Heat Shield Mortar Assembly, R8130-5

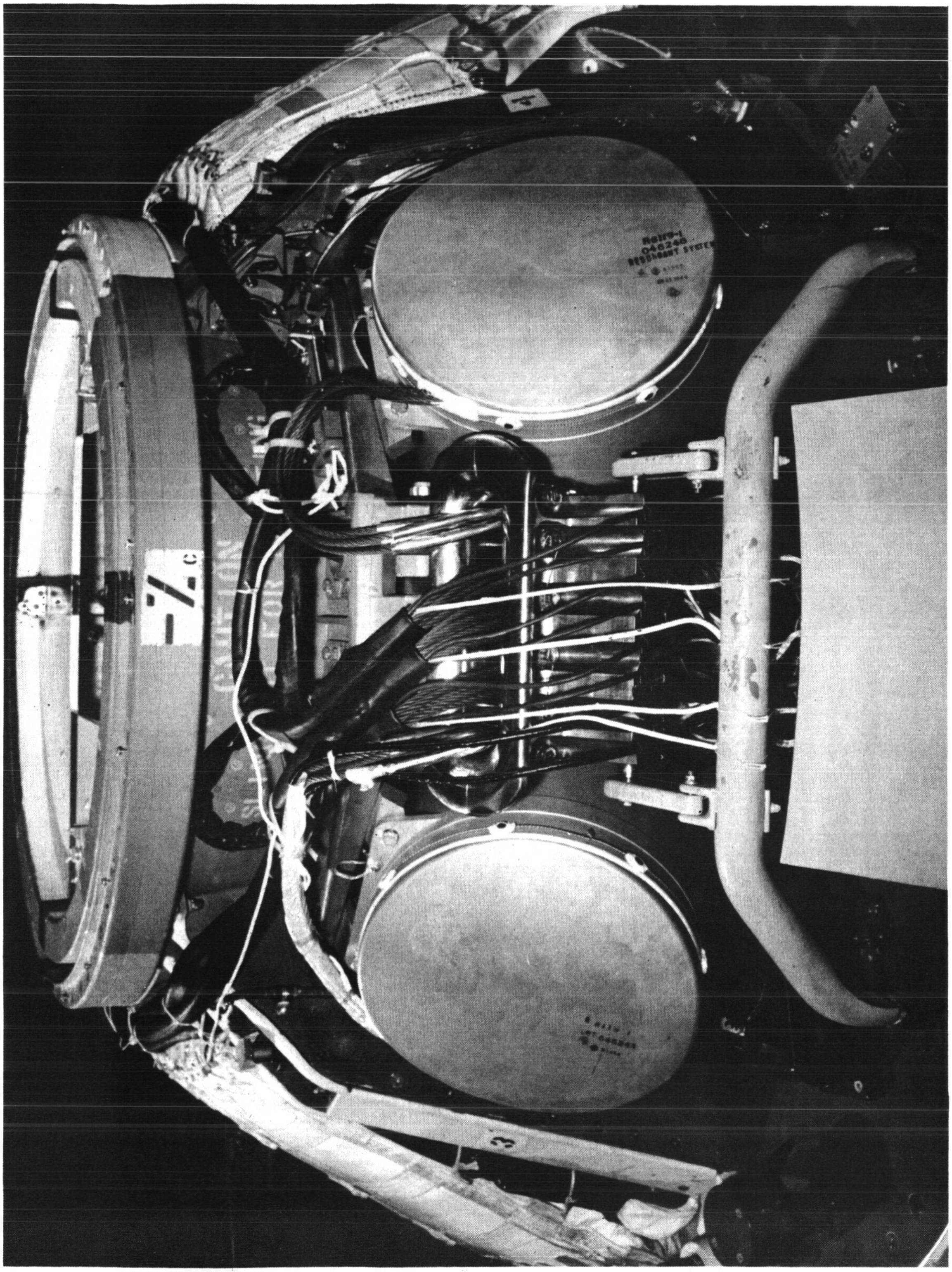


Figure 2-6. Parachute Subsystem Installation, -Z Bay

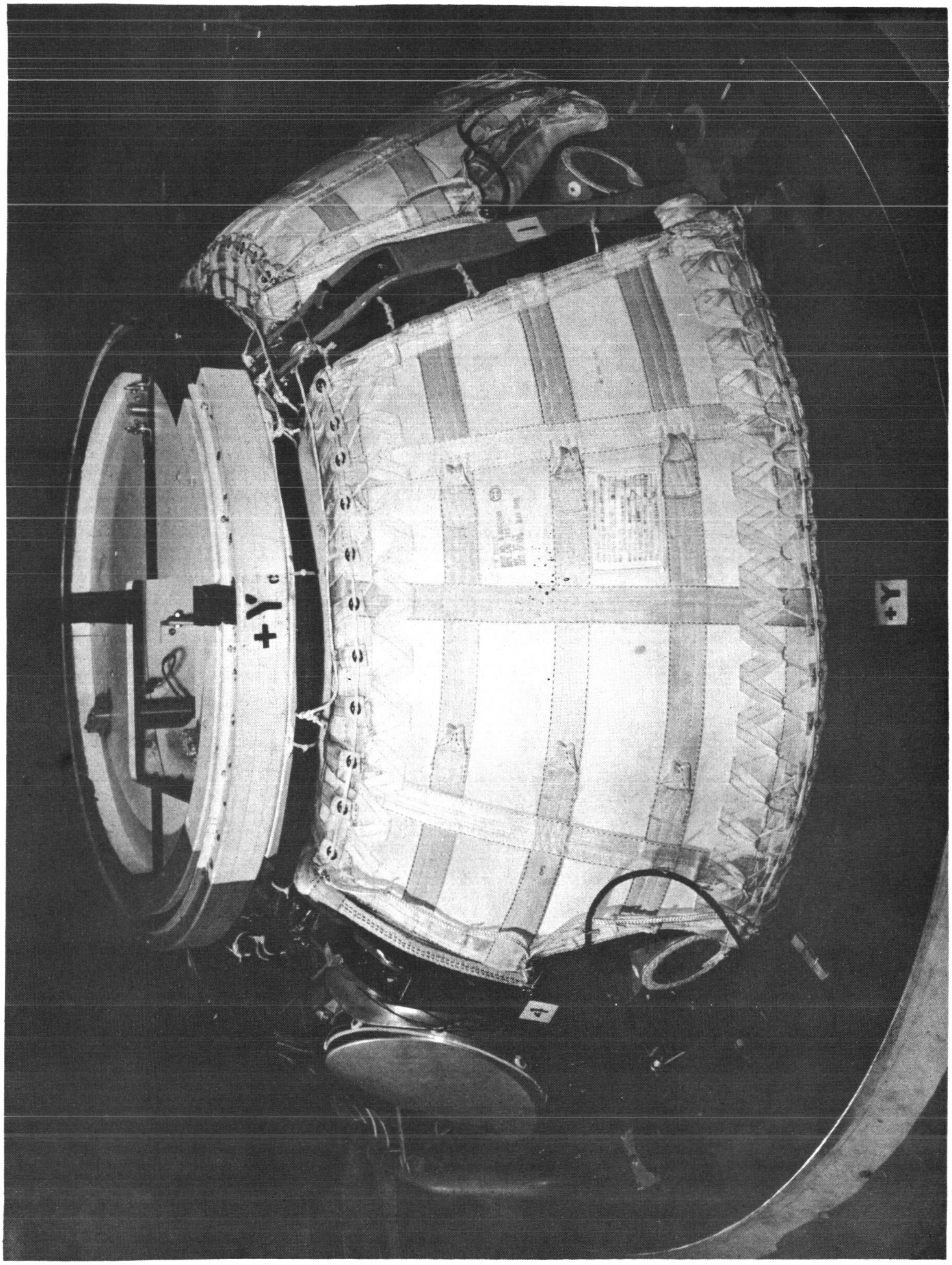


Figure 2-7. Parachute Subsystem Installation, +Y Bay

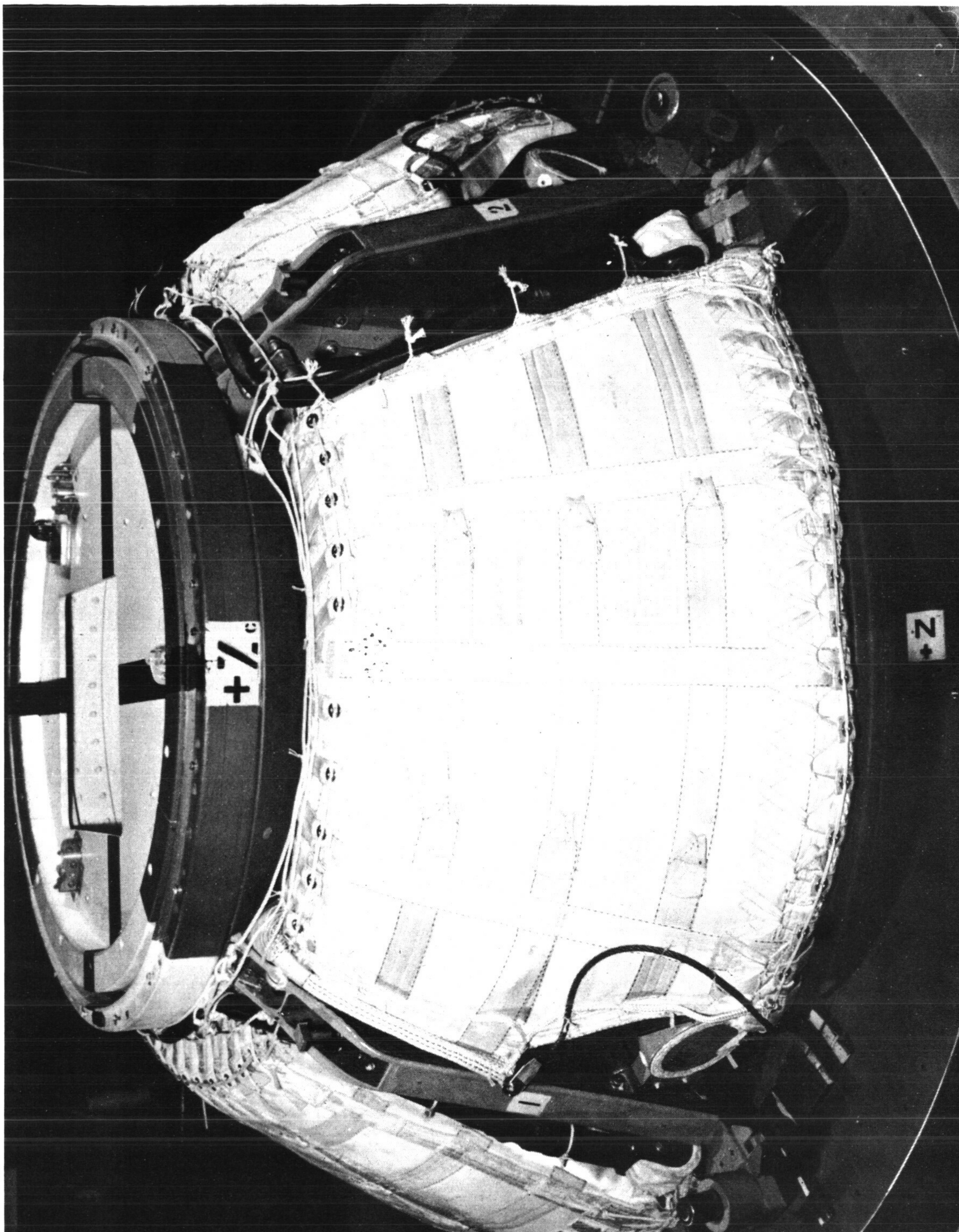


Figure 2-8. Parachute Subsystem Installation, +Z Bay

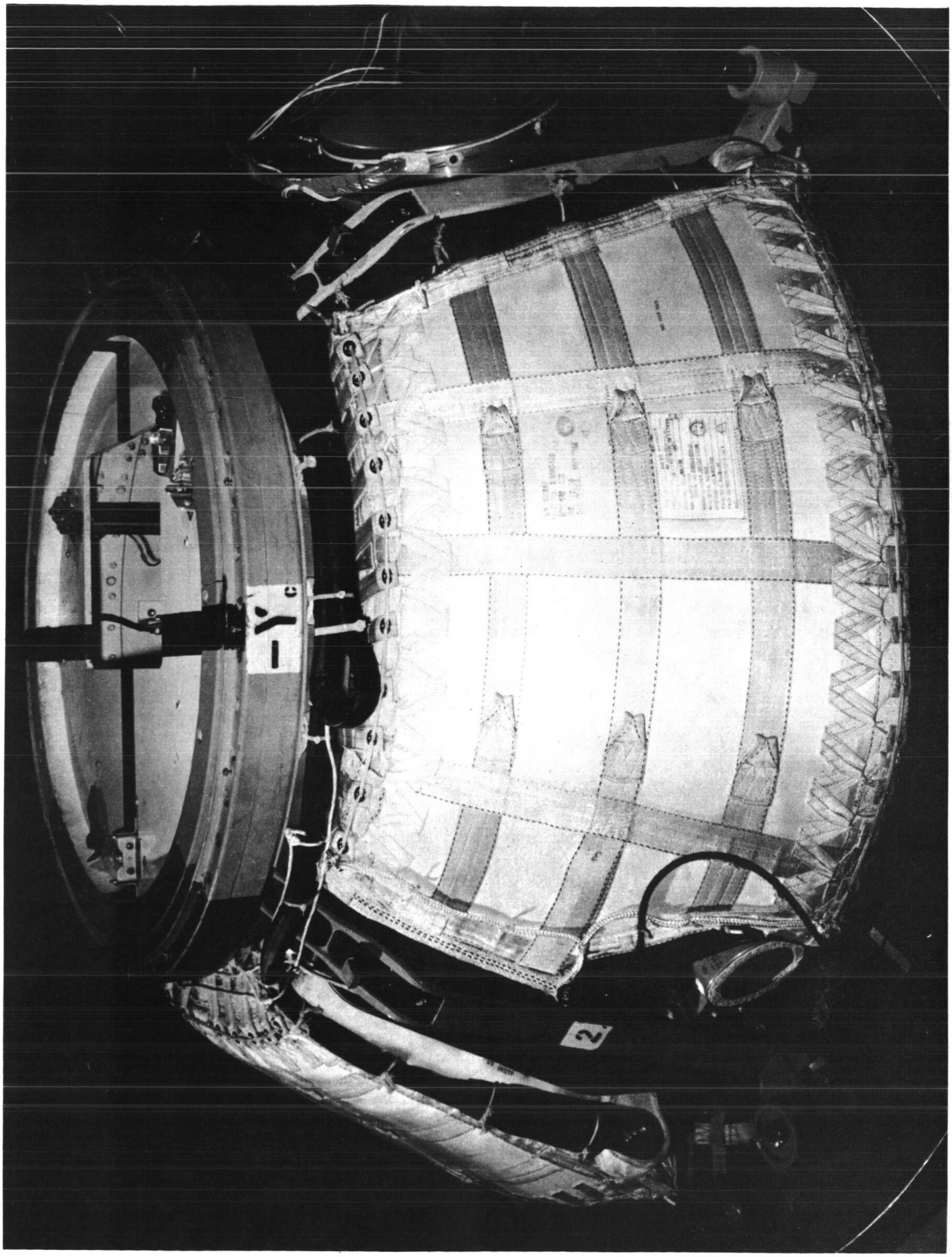


Figure 2-9. Parachute Subsystem Installation, -Y Bay

Interface and envelope compatibility was successfully demonstrated throughout the drop test program, particularly with regard to main parachute pack installations in which no installation problems were encountered. Specification requirements have been fully met without reservation.

2.13 QUALIFICATION STATUS SUMMARY

The assemblies used during the Block II Increased Capability qualification test series, their equivalents which were qualified during the earlier Block II qualification tests, the basis for qualification of the Block II Increased Capability design, and related documentation, are listed in Table 2-3.

Block II Increased Capability Parachute Subsystem ME 623-0006	Block II Equivalent Qualified per NVR 5044A	Configuration Differences Between Block II and Block II Increased Capability
Main Parachute Pack Assembly ME 623-0007-0001 R8058-503	Main Parachute Pack Assembly ME 901-0695-0001 R8058-1	Configuration identica except for incorporati of main parachute two stage reefing system.
Main Parachute Retention Assembly ME 901-0693-0001 R8091-1 (+Y, -Y Bays) ME 901-0693-0002 R8091-3 (+Z Bay)	Main Parachute Retention Assembly ME 901-0693-0001 R8091-1 (+Y, -Y Bays) ME 901-0693-0002 R8091-3 (+Z Bay)	Configuration identica earlier Block II.
Pilot Parachute Mortar Assembly ME 623-0001-0003 R8040-11	Pilot Parachute Mortar Assembly MC 623-0001-0001 R8040-7	Identical to earlier Block II except for strengthened fabric ri and modified sleeve o fabric riser.
Drogue Parachute Mortar Assembly ME 623-0008-0001 R8110-5	Drogue Parachute Mortar Assembly ME 901-0724-0001 R8020-1	This assembly was redesigned for larger parachute (16.5' D_o) c ferent reefing line and cutters and a four-cab steel riser assembly.
Main Parachute Riser Assembly ME 901-0694-0001 R8030-1	Main Parachute Riser Assembly ME 901-0694-0001 R8030-1	Configuration same as earlier Block II desig
Forward Heat Shield Mortar Assembly ME 623-0005-0002 R8130-5	Not Applicable	The forward heat shie parachute is to retard forward heat shield ar prevent it from contac the Parachute Subsyst or the Spacecraft.
Pilot Cartridge ME 453-0005-0093 58503-13	Pilot Cartridge ME 453-0005-0092 58503-11	Similar to earlier Block II design.
Drogue Cartridge ME 453-0005-0091 58502-11	Drogue Cartridge ME 453-0005-0091 58502-11	Configuration same as earlier Block II desig
Sequence Controllers* ME 901-0001-0037 R8204-1 FOLD-OUT #1	Sequence Controllers ME 901-0001-0019 R6920-517	No differences, simil to earlier Block II des

*Not contractually part of Block II Parachute Subsystem, Increased Capability.

	Basis for Qualification of Block II Increased Capability	Documentation
l on -	Similarity to earlier Block II. Block II Development Drop Tests (80, 81, 82, 83 Series). Laboratory Tests. Block II Qualitification Drop Tests (85 Series).	NVR 5044A NVR 6070 NVR 6106 NVR 6158 NVR 6198 TER 2019 TER 1961
to	By similarity to earlier Block II configuration. Block II Qualification Drop Tests (85 Series).	NVR 5044A NVR 6070 TER 1213 TER 1215
ser ver	By similarity to earlier Block II configuration. Block II Qualification Tests (Series 85).	NVR 5044A NVR 6070 TER 1359
lif- l ble	Block II Development Drop Tests (Series 84 and 99). Similarity to earlier Block II. Laboratory Qualification Tests. Series 85 Qualification Tests.	NVR 5044A NVR 6070 NVR 6078 NVR 6069 NVR 6068 NVR 6080 NVR 6079 NVR 6160 TER 2039 TER 2019
n.	By similarity to earlier Block II configuration. Series 85 Qualification Tests.	NVR 5044A NVR 6070 NVR 5000 TER 1450 TER 1364 TER 1434
ld the nd cting em	Lab. Qualification Tests Block II Qualification Tests (Series 85), Tests 85-1, 85-2, 85-3, and 85-4	NVR 6070 NVR 6078 TER 1919
	By similarity to earlier Block II cartridges. Lab. Qualification Tests Series 85 Qualification Tests.	NVR 5044A NVR 6070 TER 1919 TER 1532 and NVC/67-1126/0804
n.	Bv similarity to earlier Block II cartridges. Series 85 Qualification Tests.	TER 1534 and NVC/67-1126/0804 dated 10 Feb 1967 NVR 5044A NVR 6070 TER 2039
ar iign.	Series 85 Qualification Tests. Similar to earlier Block II.	NVR 5044A NVR 6070 TER 818

Table 2-3. Summary of Block II Increased Capability Parachute Subsystem Qualification

FOLD-OUT #2

SECTION 3.0

DESCRIPTION OF TESTS

A brief summary of the qualification drop tests is presented in the following seven paragraphs in the chronological order of occurrence. A more comprehensive analysis of the test program is in Section 4.0. Many sources of additional detailed information including the individual Northrop Ventura Preliminary Performance (TRB) Reports are listed in Section 7.0, "References." These so-called "Red Books" were prepared immediately following each test and served as the principal data package for evaluation and classification of the test by the Technical Review Board.

3.1 QUALIFICATION DROP TEST NO. 85-1

The objective of this test was to demonstrate Parachute Subsystem performance under conditions simulating those expected during a normal entry.

The test was conducted at 1007 hours on Thursday, 4 April 1968. The test vehicle was dropped from the carrier aircraft at an altitude of 30,000 feet and an equivalent airspeed of 126 knots. Static line deployment of the programmer parachute, and subsequent orientation of vehicle attitude to the desired 165° angle of attack were accomplished as planned. After approximately 29 seconds of operation the programmer parachute was disconnected. The forward heat shield was ejected, and the forward heat shield mortar deployed its respective parachute which successfully augmented the separation of the jettisoned heat shield.

Drogue mortar fire occurred approximately two (2) seconds later. Deployment of the drogue parachutes was normal; however, some vehicle oscillations were present and they increased substantially at drogue disreef. This vehicle oscillation decayed rapidly after drogue disreef and had decreased appreciably at the time of drogue disconnect and pilot mortar fire. Extraction and deployment of the main parachutes was as expected. All three main parachutes disreefed from both stages and inflated normally to full open. Descent to impact was without incident with touchdown and main parachute disconnect occurring 352.6 seconds after launch.

3.2 QUALIFICATION DROP TEST NO. 85-3

The objective of this test was to demonstrate Parachute Subsystem performance during conditions simulating those expected during a normal entry with a programmed failure of one drogue parachute mortar assembly.

The test was conducted at 1015 hours on Wednesday, 24 April 1968. The test vehicle was launched at an altitude of 32,500 feet at an equivalent airspeed of 126 knots. Static line deployment of the programmer parachute was as planned. The required attitude, with an angle of attack of 165°, was obtained; but the test vehicle possessed large body rates similar to those expected from a high-altitude abort case. After programmer disconnect, the forward heat shield was ejected and successfully augmented by normal operation of the forward heat shield mortar assembly. The boilerplate pitched over after ejection of the forward heat shield. A single drogue parachute was successfully mortar-deployed. At drogue canopy stretch the boilerplate was jerked over violently producing large oscillations. These extreme oscillations were expected due to deployment of only one drogue parachute but were made worse by the large body rates. Abrasive contact between the drogue steel riser and the disconnect assembly (flowerpot) caused many of the wire strands in the drogue riser to be worn and mashed and caused several strands to be broken. At drogue disconnect the pitch and yaw rates were evident but somewhat reduced. The roll rate, however, still was large.

Deployment of the pilot parachutes and subsequent extraction and deployment of the main parachutes occurred as expected. The main parachute steel risers were wrapped up during deployment due to the residual vehicle roll rate. This did not affect the operation of the main parachutes but did damage the main parachute loads instrumentation. All loads were lost with only the first-stage loads (F_{R_1}) from one main parachute being obtained.

Steady state descent on the main parachutes was without further incident. Ground touchdown and main parachute disconnect occurred 173.0 seconds after launch.

3.3 QUALIFICATION DROP TEST NO. 85-2

The objective of this test was to demonstrate the operational performance of the Parachute Subsystem during conditions simulating a pad abort case.

This test was conducted on Wednesday, 1 May 1968. The boilerplate test vehicle was launched at an altitude of 11,436 feet and at an equivalent airspeed of 116 knots. Launch and operation of the programmer parachute were as expected. The test vehicle achieved the desired altitude during the programmer phase and retained it during the freefall prior to drogue mortar fire. The forward heat shield was ejected and successfully augmented by normal operation of the forward heat shield mortar assembly.

The drogue parachutes were mortar deployed, and when the drogue parachutes inflated, they caused large pitch and yaw oscillations. These oscillations remained with the vehicle throughout the short drogue phase; however, they were damped to some extent at drogue disconnect.

During the freefall following drogue disconnect, the test vehicle continued to oscillate and it did not have the desired attitude at main parachute canopy stretch. The torque applied by the main parachute risers caused large oscillation rates in the test vehicle. These oscillations were damped out very quickly under the main parachutes.

Steady state descent was without further incident. Ground touchdown and disconnect of the main parachutes occurred 214.0 seconds after launch.

3.4 QUALIFICATION DROP TEST NO. 85-6

The objective of this test was to demonstrate the performance of the Parachute Subsystem during a simulated pad abort while simulating manual override of the drogue parachutes.

The test was conducted at 1050 hours on Tuesday, 14 May 1968. The boilerplate was launched from the carrier aircraft at an altitude of 10,371 feet and at an equivalent airspeed of 170 knots. A programmer parachute was not used for this test. The boilerplate pitched over (apex aft) after separation from the carrier aircraft and began to pitch forward to a horizontal attitude at pilot mortar fire. Thus, the desired vehicle attitude for a pad abort was attained during the three-second freefall period following launch.

Mortar deployment of the pilot parachutes was accomplished in a normal manner with the subsequent extraction and deployment of the main parachutes being nearly simultaneous. The test vehicle pitched over at main parachute line stretch due to the loads imposed by the main parachute risers. The oscillations created were large but they were substantially reduced to very small values following the first-stage reefed condition.

Steady state descent to impact was normal and without incident. Touchdown occurred approximately 281.2 seconds after launch with the main parachutes disconnecting as planned.

3.5 QUALIFICATION DROP TEST NO. 85-5

The objective of this test was to demonstrate Parachute Subsystem performance under conditions simulating a high-altitude abort with a simulated failure of one drogue mortar assembly.

The test was conducted at 1109 hours on Thursday, 6 June 1968. The test vehicle was dropped from the carrier aircraft at an altitude of 31,432 feet and at an equivalent airspeed of 139 knots. Static line deployment and operation of the programmer parachute were normal. The test vehicle was very stable during the freefall phase with the apex forward. This attitude remained until first-stage reefed inflation of the drogue parachute when the vehicle was turned to the normal descent position (aft heat shield forward) by the drogue parachute. This action caused large amplitude oscillations. These oscillations were expected and were nearly damped out completely prior to drogue disconnect.

Mortar deployment of the pilot parachutes and subsequent extraction and deployment of the main parachutes were normal. Disreef of the main parachutes into second stage and to full open was without incident. Descent to impact was normal with touchdown and main parachute disconnect occurring 164.0 seconds after launch.

3.6 QUALIFICATION DROP TEST NO. 85-4

The objective of this test was to demonstrate the operational performance of the Parachute Subsystem during a normal entry simulation with a programmed cartridge failure in one drogue mortar assembly. The test vehicle weighed approximately 13,500 pounds, which was 500 pounds overweight.

This test was conducted at 0921 hours on Monday, 17 June 1968. The test vehicle was dropped from the launch aircraft at an altitude of 33,438 feet and an equivalent airspeed of 130 knots. The launch conditions and static line deployment of the programmer parachute were as planned with the desired angle of attack of 165° being achieved. However, the drag area of the boilerplate and programmer parachute combined was slightly lower than predicted at programmer disconnect. The forward heat shield was jettisoned, and the forward heat shield mortar assembly deployed its respective parachute as planned.

Drogue parachute deployment and operation were normal. During drogue parachute operation, the test vehicle was moderately unstable in pitch and yaw. The pitch and yaw rates were damped substantially prior to disconnect. A roll rate began to build up after drogue disreef and reached a maximum of 120 degrees/second at drogue disconnect.

The pilot parachutes were mortar deployed and successfully extracted and deployed the main parachutes. A substantial residual roll rate remained with the test vehicle and caused the main parachute steel risers to wrap up during deployment. The torque generated by the wrapped risers imparted a reverse roll to the vehicle which remained until impact.

Steady state descent to ground touchdown was normal; however, the main parachute steel risers remained twisted together until impact. Ground touchdown and disconnect of the main parachutes occurred 180.6 seconds after launch.

3.7 QUALIFICATION DROP TEST NO. 85-7

The objective of this test was to demonstrate the performance capability of the Parachute Subsystem during a high altitude abort simulation with programmed failures of one drogue mortar assembly and one pilot mortar assembly.

This test was conducted at 0924 hours on 3 July 1968. The test vehicle was dropped from the carrier aircraft at an altitude of 32,800 feet and at an indicated airspeed of 142 knots. Launch and static line deployment of the programmer parachute were as planned with the boilerplate achieving an apex forward attitude. The boilerplate retained this attitude throughout the free-fall phase following programmer disconnect. Mortar deployment and operation of the single drogue parachute were normal. Oscillations during the initial drogue phase were violent. These oscillations were in one plane, but changed to a combination of pitch, roll, and yaw. The pitch and yaw rates were damped substantially prior to drogue disconnect; however, a roll rate remained with the vehicle until after main parachute deployment.

Mortar deployment of the two pilot parachutes and the subsequent extraction and deployment of two main parachutes occurred as planned. The main parachute steel risers were wrapped up due to the vehicle roll rate. Disreef to second-stage and full open and steady state descent utilizing only two main parachutes were without incident. Touchdown occurred 157.0 seconds after launch, and resulted in the vehicle tipping over after impact.

SECTION 4.0

DATA SUMMARY AND ANALYSIS

Significant data acquired during the qualification drop tests of the Apollo Block II Increased Capability Program appear in this section. They are displayed in tables and charts to provide ready reference and comparison. Various plotted and graphic data are provided to permit a detailed analysis and evaluation of Parachute Subsystem performance. Additional data may be found in Appendix D.

4.1 COMPARISON OF PLANNED AND ACTUAL TEST CONDITIONS

The conditions at significant event times during each test are listed in Table 4-1. These conditions include time, dynamic pressure, altitude, and disreef times for each parachute test specimen along with the final descent weight and rate of descent. The actual values for times, dynamic pressures, and altitudes are compared to the predicted values in Table 4-2. For cluster parachute operations; however, only the actual test data from the lead parachute are compared with that predicted.

In each case, the predicted values were determined from a two degree-of-freedom point-mass computer program. Actual times for launch, programmer parachute disconnect, and drogue and main parachute initiation and disconnect were obtained from monitored electrical events. Actual times for drogue and main parachute disreef were obtained from analysis of photographic coverage in conjunction with the monitored electrical events. Altitude and dynamic pressure were obtained from Askania using actual atmospheric data from a Rawinsonde system. Predicted parameters were derived from standard day atmosphere, specified launch altitudes, nominal pressure altitude baroswitch closures, and average vehicle drag areas based on assumed

TEST NO. AND DATE		LAUNCH CONDITIONS				PROGRAMMER PARACHUTE DISCONNECT			FORWARD HEATSHIELD JETTISON			DROGUE MORTAR FIRE			DROGUE PARACHUTE LINE STRETCH			DRC PARA DISR	
TEST NO.	TEST DATE.	GROSS VEHICLE WEIGHT (LBS)	LAUNCH AIRCRAFT AIRSPEED (KEAS)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME AFTER LAUNCH (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE
85-1	4/4/68	13,323	131.5	58.7	30,929	29.59	75.5	23,129	29.59	75.5	23,129	31.35	87.4	22,474	32.01	90.0	22,218	42.49 42.40	6 6
85-3	4/24/68	13,312	127.3	55.0	33,330	28.89	100.0	25,150	28.89	100.0	25,150	30.65	115.0	24,400	31.49	121.0	23,998	42.44	10
85-2	5/1/68	13,345	116.3	45.9	11,436	4.95	45.0	11,090	4.95	45.0	11,090	6.72	54.0	10,811	7.45 7.46	59.0 59.0	10,669 10,667	17.65 17.88	5 5
85-6	5/14/68	13,038	177.9	107.5	10,371	NO PROGRAMMER USED			NO FORWARD HEATSHIELD			DROGUE PARACHUTES NOT USED FOR THIS TE							
85-5	6/6/68	12,981	149.6	76.0	31,432	14.96	42.7	28,961	NO FORWARD HEATSHIELD			36.47	170.5	19,564	37.03	170.5	19,274	47.52	10
85-4	6/17/68	13,788	133.5	60.5	33,438	29.1	79.6	25,632	29.1	79.6	25,632	30.88	92.5	24,937	31.48	95.0	24,692	41.49	9
85-7	7/3/68	12,990	141.3	67.8	32,802	20.08	42.0	28,940	NO FORWARD HEATSHIELD			35.40	149.5	22,468	36.02	150.5	22,153	45.75	1

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#1

GUE CHUTE EEF		DROGUE DISCONNECT AND PILOT MORTAR FIRE			MAIN PARACHUTE LINE STRETCH			MAIN PARACHUTE 1ST STAGE DISREEF			MAIN PARACHUTE 2ND STAGE DISREEF			MAIN PARACHUTE FULL OPEN		STEADY STATE DESCENT			TEST NUMBERS	
(PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	DYNAMIC PRESSURE (PSF)	ALTITUDE (FT) MSL	TIME (SEC)	ALTITUDE (FT) MSL	FINAL DESCENT WEIGHT (LBS)	AVERAGE RATE OF DESCENT (FPS) (COM MSL)	IMPACT TIME (SEC)	NV TEST NO.	USAF TEST NO.
4.5 4.0	18,644 18,672	74.77	39.4	10,890	77.03 76.97 77.15	56.0 55.8 56.3	10,355 10,370 10,324	83.16 83.25 83.45	15.2 15.0 14.5	9,195 9,183 9,157	87.71 87.55 87.88	4.4 4.50 4.2	8,771 8,782 8,759	93.35 89.57 90.82	8,514 8,665 8,618	12,936	31.7	356	85-1	0678F
9.0	19,219	92.99	63.7	4,535	94.84 94.97 95.06	77.5 77.8 78.0	4,050 4,012 3,987	101.11 101.28 101.29	16.3 16.0 16.3	2,830 2,808 2,806	105.37 105.58 105.40	4.5	2,660 2,444 2,455	107.95 109.11 108.57	2,328 2,289 2,307	12,965	31.9	179	85-3	0804F
3.0 7.5	8,301 8,243	18.95	55.2	7,980	20.81 21.05 20.96	73.1 73.3 73.4	7,490 7,425 7,451	27.04 27.0 26.96	13.5 13.8 13.8	6,305 6,309 6,315	31.14 31.38 31.24	4.3 4.1 4.2	5,950 5,936 5,945	35.98 34.88 34.26	5,750 5,775 5,795	12,958	29.3	217	85-2	0890F
ST		3.0	92.3	10,240	4.73 4.69 4.80	88.9 89.0 88.8	10,027 10,032 10,017	10.93 11.07 11.00	14.5 14.0 14.3	9,211 9,193 9,202	15.16 15.24 15.44	3.80 3.80 3.70	8,839 8,834 8,821	17.99 17.86 18.38	8,699 8,703 8,687	12,988	34.2	282.4	85-6	0978F
9.5	14,710	84.81	63.5	4,175	86.89 86.80 86.82	74.5	3,642 3,656 3,651	93.07 92.84 92.96	13.9 15.0 14.2	2,592 2,618 2,604	97.32 97.20 97.25	4.1 4.2 4.2	2,248 2,255 2,252	99.99 99.85 104.27	2,114 2,119 1,967	12,941	32.8	167.0	85-5	1053F
8.9	20,696	96.45	65.1	4,336	98.37 98.34 98.34	77.1	3,812 3,820 3,820	104.1 104.31 104.17	15.7 15.0 15.5	2,706 2,680 2,697	108.34 108.52 108.26	4.3 4.2 4.3	2,344 2,332 2,349	111.75 112.00 111.09	2,190 2,183 2,211	13,442	28.4	183.0	85-4	1141F
09.0	17,812	91.59	63.3	4,399	93.72 93.56	76.4 76.2	3,832 3,949	99.72 99.71	24.5 24.5	2,567 2,569	104.02 103.92	7.0 7.1	2,103 2,108	107.49 106.09	1,922 1,977	12,949.0	34.7	160.0	85-7	1208F

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#2

Table 4-1. Test Data Summary

Event		85-1 Planned	Actual	85-2 Planned	Actu
Launch	Time Alt. "q"	0 30,000 57.5	0 30,929 58.7	0 11,000 49.0	0 11,4 45.
Disconnect Programmer Chute	Time Alt. "q"	29.7 22,000 80.6	29.59 23,129 75.5	5.0 10,635 44.0	4. 11,0 45.
Fire Drogue Chute Mortars	Time Alt. "q"	31.4 21,360 90.6	31.35 22,474 87.4	6.7 10,365 51.3	6. 10,8 54.
Drogue Chute Line Stretch	Time Alt. "q"	32.0 21,130 93.9	32.01 22,218 90.0	7.3 10,250 54.3	7. 10,6 59.
Disreef Drogue Chutes	Time Alt. "q"	42.6 17,610 61.9	42.40 18,672 64.0	17.9 7,890 55.4	17. 8,3 58.
Disconnect Drogue Chutes and Fire Pilot Mortars	Time Alt. "q"	71.7 10,750 41.8	74.77 10,890 39.4	18.7 7,700 52.2	18. 7,9 55.
Main Chute Line Stretch	Time Alt. "q"	73.6 10,250 58.2	76.97 10,370 55.8	20.6 7,230 68.4	20. 7,4 73.
First Disreef Main Chutes	Time Alt. "q"	80.0 8,950 17.2	83.16 9,195 15.2	27.0 6,025 17.0	26. 6,3 13.
Second Disreef Main Chutes	Time Alt. "q"	84.2 8,590 4.2	87.55 8,782 4.5	31.2 5,680 4.1	31. 5,9 4.
Impact and Main Chutes Disconnect	Time Alt. "q"	360.0 0 1.0	356.0 0 1.26	216.0 0 1.0	217. 0 1.

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*Poor Data Quality

	Drop Test Number									
al	85-3 Planned	85-3 Actual	85-4 Planned	85-4 Actual	85-5 Planned	85-5 Actual	85-6 Planned	85-6 Actual	85-7 Planned	85-7 Actual
	0	0	0	0	0	0	0	0	0	0
36	30,000	33,330	32,000	33,438	32,000	31,432	10,000	10,371	32,000	32,802
9	57.5	55.0	57.5	60.5	66.5	76.0	98.0	107.5	66.5	67.8
95	29.0	28.89	29.0	29.1	15.0	14.96			20.0	20.08
90	21,900	25,150	23,865	25,632	29,490	28,961			28,150	28,940
0	95.7	100.0	87.9	79.6	36.9	42.7			38.5	42.0
72	30.7	30.65	30.7	30.88	36.7	36.47	NO DROGUE PARACHUTES		35.25	35.40
11	21,200	24,400	23,180	24,937	20,000	19,564			21,840	22,468
0	103.8	115.0	99.0	92.5	174.1	170.5			150.0	149.5
45	31.3	31.49	31.3	31.48	37.2	37.03			35.85	36.02
59	20,960	23,998	22,930	24,692	19,740	19,274			21,540	22,153
0	106.5	121.0	102.8	95.0	175.8	170.5			153.3	150.5
55	41.9	42.44	41.9	41.49	47.8	47.52			46.45	45.75
01	16,975	19,219	18,720	20,696	15,059	14,710			16,910	17,812
0	86.6	109.0*	95.1	98.9	114.8	109.5			109.2	109.0
95	84.5	92.99	89.5	96.45	83.0	84.81	3.0	3.0	88.0	91.59
30	5,000	4,535	5,000	4,336	5,000	4,175	9,860	10,240	5,000	4,399
2	64.1	63.7	66.6	65.1	64.1	63.5	80.2	92.3	64.1	63.3
31	86.4	94.84	91.4	98.34	84.9	86.80	4.8	4.69	89.9	93.56
90	4,550	4,050	4,385	3,820	4,450	3,656	9,660	10,032	4,495	3,949
1	80.0	77.5	84.9	77.1	80.0	74.5	78.8	89.0	81.9	76.2
96	92.8	101.11	97.8	104.10	91.3	92.84	11.2	10.93	96.3	99.71
15	3,365	2,830	3,200	2,706	3,260	2,618	8,830	9,211	3,175	2,569
3	16.9	16.3	16.3	15.7	16.8	15.0	15.2	14.5	23.7	24.5
14	97.0	105.37	102.0	108.26	95.50	97.20	15.4	15.16	100.5	103.97
50	3,040	2,460	2,870	2,349	2,940	2,255	8,485	8,839	2,770	2,108
3	4.1	4.5	4.3	4.3	4.1	4.2	4.13	3.8	6.3	7.1
0	197.0	179.0	195.0	183.0	193.0	167.0	286.0	282.0	175.0	160.0
	0	0	0	0	0	0	0	0	0	0
11	1.0	1.25	1.1	1.09	1.0	1.42	1.0	1.42	1.5	1.50

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Table 4-2. Comparison of Planned and Actual Test Conditions vehicle attitudes and body rates. Since predicted parameters originate from average or nominal conditions, actual achieved values can be expected to differ from those predicted within the tolerances specified in the Flight Readiness Review Data Packages.

Launch conditions for all tests were close to planned conditions. The largest variations in launch conditions were the dynamic pressures for Tests 85-5 and 85-6. For both tests, the dynamic pressure was 9.5 psf higher than predicted. These variations did not affect recovery system deployment and operation. The resulting dynamic pressure at main parachute line stretch for Test 85-6 was 89.0 psf which is closer to design than planned.

The programmer parachutes performed well attaining near planned altitudes and dynamic pressures at disconnect. The vehicle pitched apex forward between programmer disconnect and drogue line stretch during Test 85-3. This caused low vehicle drag and therefore a larger increase in dynamic pressure than anticipated. The dynamic pressure attained, however, was within the design envelope.

In the case of the one drogue with 13,000 lb load, at drogue disconnect the dynamic pressure ranged from 63.3 psf to 63.7 psf at an altitude of approximately 5,000 feet. This value is substantially lower than the design value of 70 psf at 5,000 ft altitude. At 10,000 feet the dynamic pressure would be somewhat higher, but still less than the design value.

At main parachute first stage disreef, the dynamic pressures for all tests were very close to predicted, except for Test 85-2. For this test, this value was 13.8 psf instead of 17 psf predicted. The other three-main parachute test dynamic pressures ranged from 15 psf to 16.3 psf. The two-main test dynamic pressure was 24.5 psf.

Second stage disreef of the main parachute for the drop tests achieved dynamic pressures of 4.2 psf to 4.5 psf for the three-main cases. For the two-main case, 7.1 psf was achieved.

In general, comparisons of predicted and actual values show good agreement. None of the discrepancies were of a magnitude that prevented fulfillment of either the primary or secondary objectives of the tests.

4.2 .VEHICLE OSCILLATION RATES

Pitch, yaw, and roll oscillation rates were obtained from data telemetered from on-board rate instruments. Vehicle attitude instrumentation was also on-board but did not function properly. Table 4-3 presents a comparison of vehicle oscillation rates at critical event times for each of the qualification drop tests. Figures 4-1 through 4-8 present the rate-time history of each test. Peak oscillation rates of the cycle just prior to programmer and drogue parachute disconnect determine the vehicle attitude at apex cover jettison, drogue mortar fire, and pilot mortar fire.

The tests are grouped into three difference categories to simulate normal entry, high altitude abort, and pad abort. Tests 85-1, 85-3 and 85-4 simulate normal entry. Tests 85-5 and 85-7 simulate high altitude abort. Tests 85-2 and 85-6 simulate pad abort.

Of the normal entry tests, Test 85-3 had larger oscillations. This was expected because the programmer parachute had a smaller drag area (permanent reefed) than Tests 85-1 or 85-4. Film analysis shows the vehicle tumbling early in the drogue phase of Test 85-3 but gradually damping during drogue operation (larger parachute drag area). The roll rate build-up during drogue operation continued through main parachute operation resulting in metal riser wrap-up. This same roll rate condition occurred in Test 85-4. Test 85-4 used a vehicle 500 pounds heavier than in all other tests. This caused farily high oscillations but not as large as in Test 85-3.

EVENT		TEST 85-1			TEST 85-2			TEST 85-3	
		PITCH	YAW	ROLL	PITCH	YAW	ROLL	PITCH	YAW
BRAKE PARACHUTE OPERATIONS	VEHICLE RATES JUST PRIOR TO BRAKE PARACHUTE DISCONNECT...	+16 -3	+37 -47	+2 -12	-44 +49	-58 +60	-3 +3	-33 +47	-131 +135
	...PEAK RATES DURING BRAKE PARACHUTE OPERATION...	+60 -64	+94 -102	+18 -20	-44 +49	-58 +60	-3 +3	-49 +48	-131 +135
	...AND AT BRAKE PARACHUTE DISCONNECT	0	-47	-11	+43	-54	-1	+20	+97
DROGUE PARACHUTE OPERATION	VEHICLE RATES AT DROGUE MORTAR FIRE...	+5	+41	-14	-25	+15	+2	-147	-108
	...PEAK RATES DURING DROGUE PARACHUTE OPERATION...	+90 -64	+148 -131	+46 -51	-104 +119	-99 +85	-42 +49	— —	-205 +182
	...AND JUST PRIOR TO DROGUE PARACHUTE DISCONNECT	+17 -8	+16 -23	+11 -4	-100 +114	-99 +68	-20 +49	— —	-72 +16
PILOT MORTAR FIRE	VEHICLE RATES AT PILOT MORTAR FIRE	+3	-23	-2	+21	+63	+48	-6	-28

FOLD-OUT #1

	TEST 85-4			TEST 85-5			TEST 85-6			TEST 85-7		
ROLL	PITCH	YAW	ROLL	PITCH	YAW	ROLL	PITCH	YAW	ROLL	PITCH	YAW	ROLL
RATE (DEG/SEC)												
+11 +38	-12 +14	-71 +73	-6 +15	-164 +175	-30 +14	-11 +14	— —	— —	— —	-15 +20	-43 +16	-29 -1
-15 +38	-62 +50	-97 +106	-24 +26	-199 +182	-130 +93	-41 +40	— —	— —	— —	-165 +201	-202 +105	-120 +61
+22	-15	-67	-6	+108	-3	-4	—	—	—	-14	-5	-21
+16	+9	+75	-6	+11	-8	-4	—	—	—	+2	-17	-1
— —	-180 +183	-142 +140	-37 +115	-191 +199	-126 +132	-51 +64	— —	— —	— —	-195 +200	-74 +51	-15 +70
— —	-47 +45	-86 -25	+93 +115	-64 +71	-36 +29	-11 +6	— —	— —	— —	-43 +56	-64 +6	+52 +70
+65	+13	-38	+104	+7	+20	-8	-19	+22	+1	+40	-54	+61

FOLD-OUT #2

Table 4-3. Comparison of Vehicle Oscillation Rates

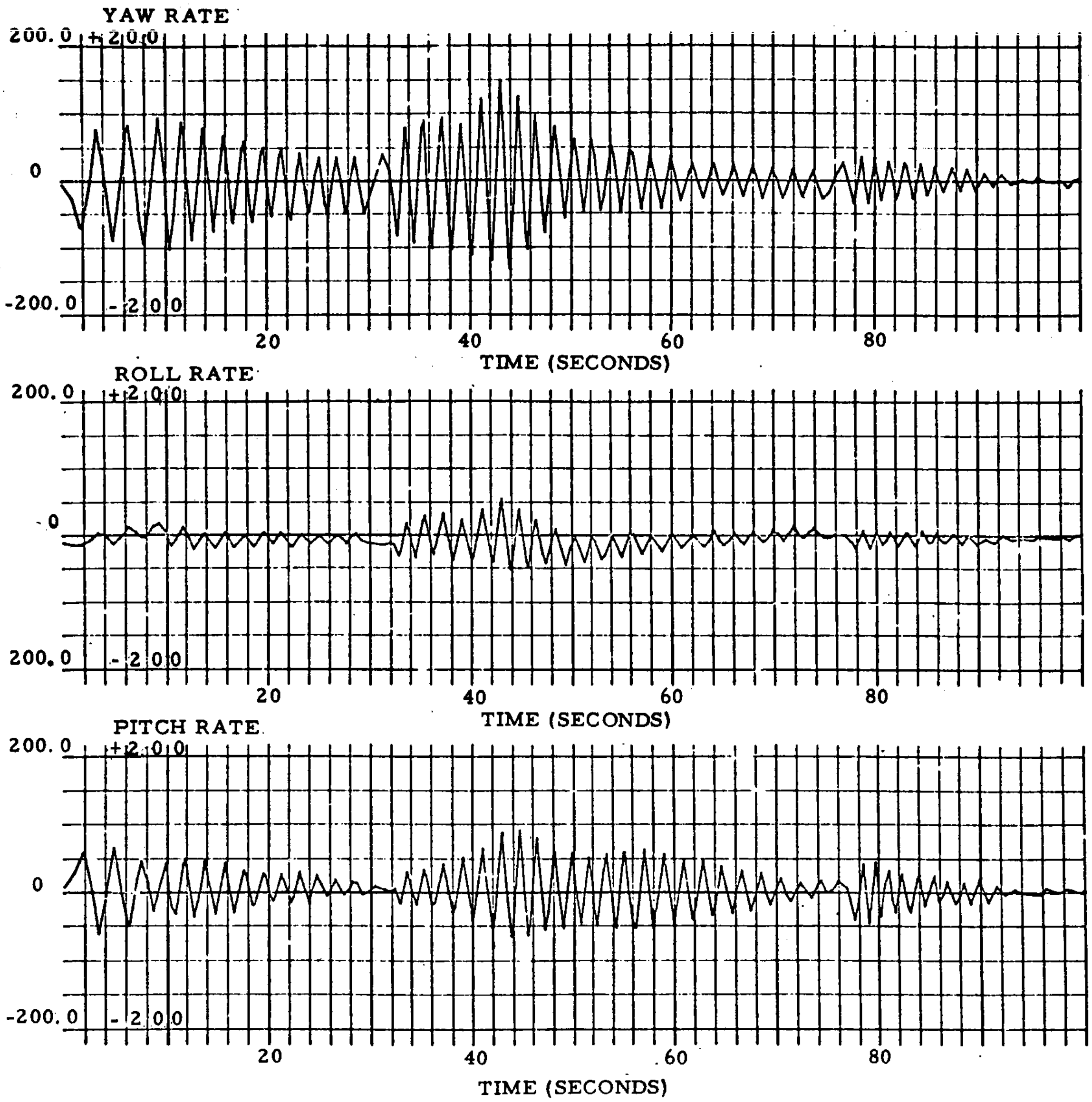

Figure 4-1. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-1

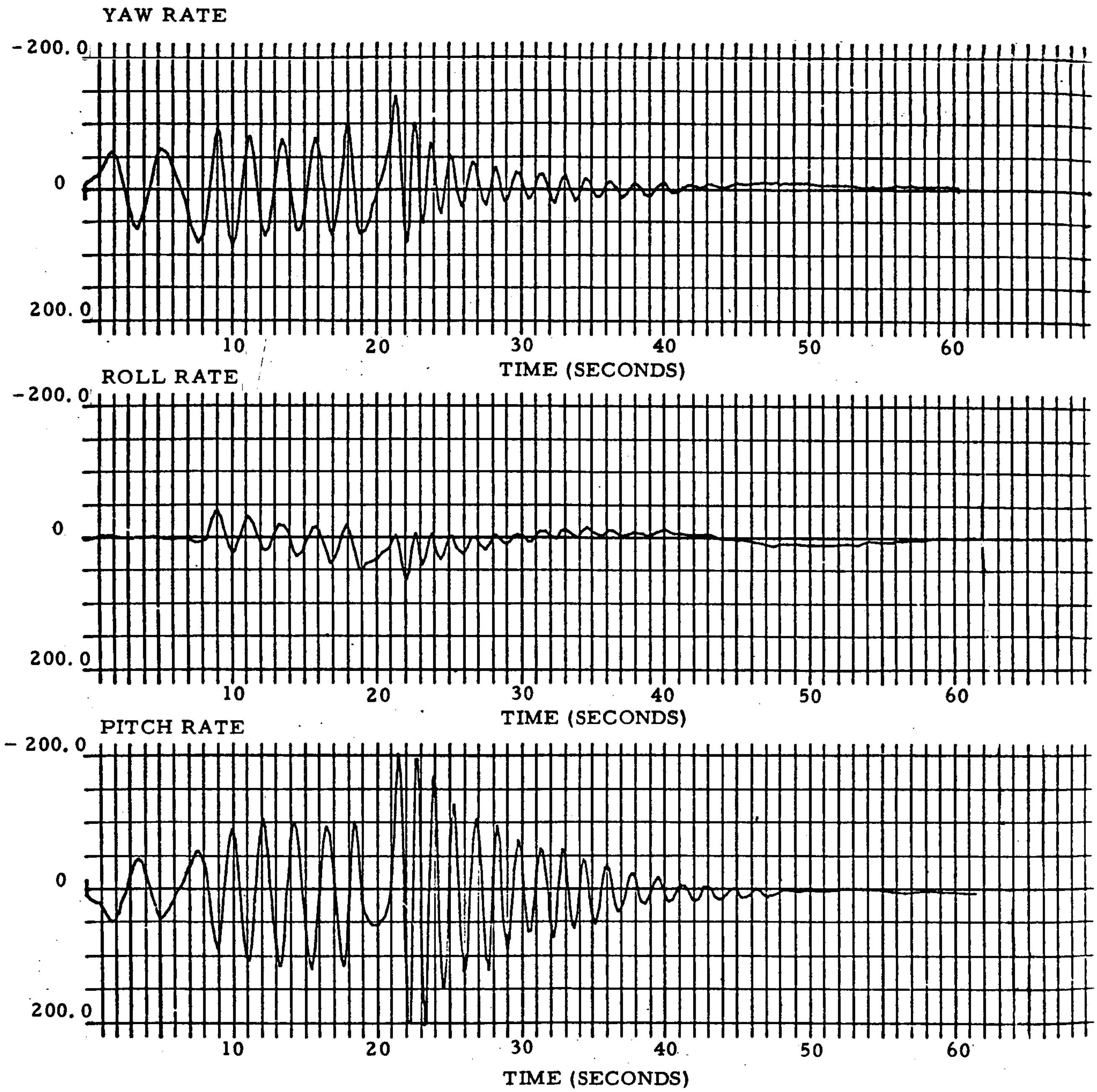

Figure 4-2. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-2

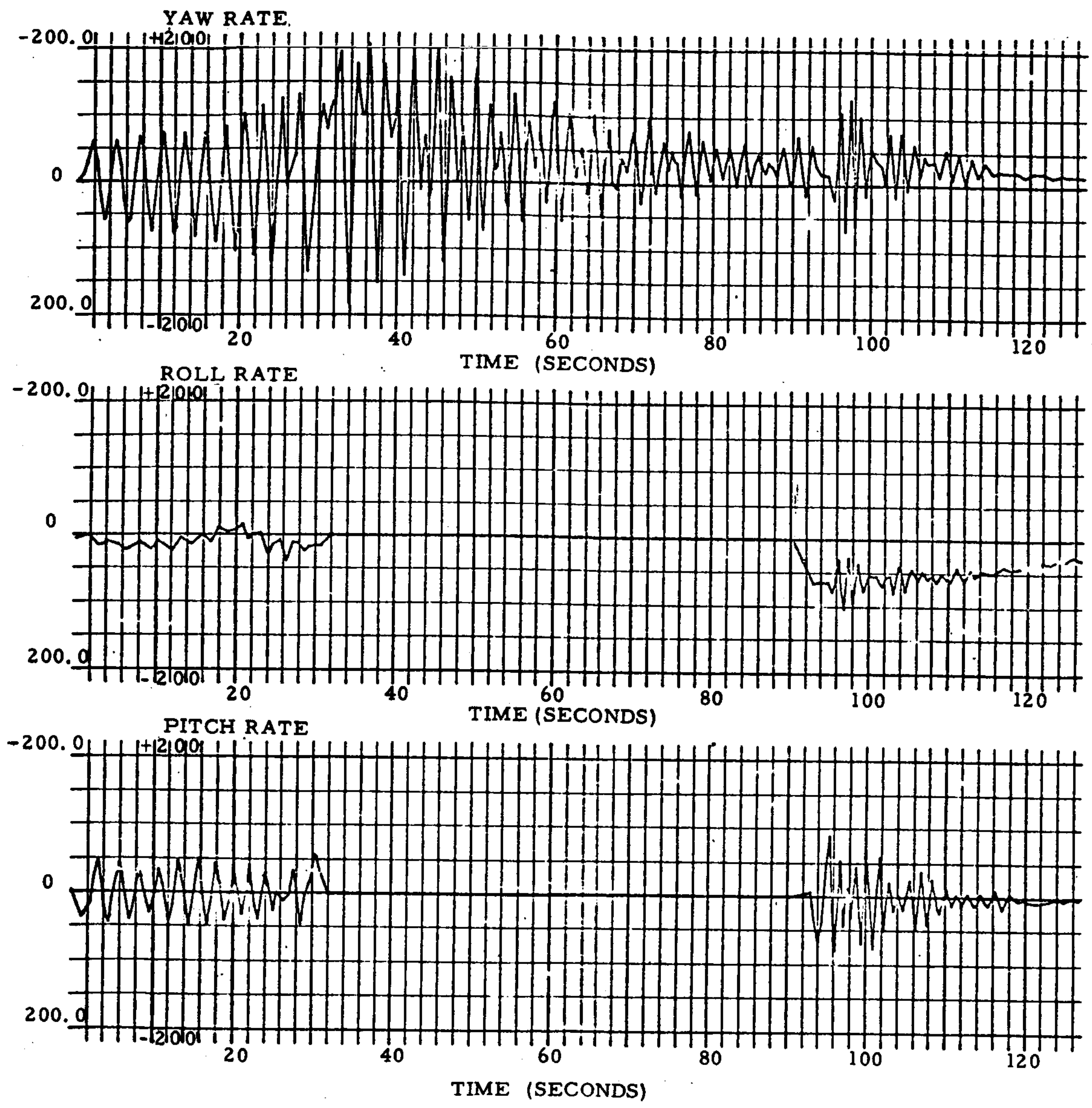

Figure 4-3. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-3

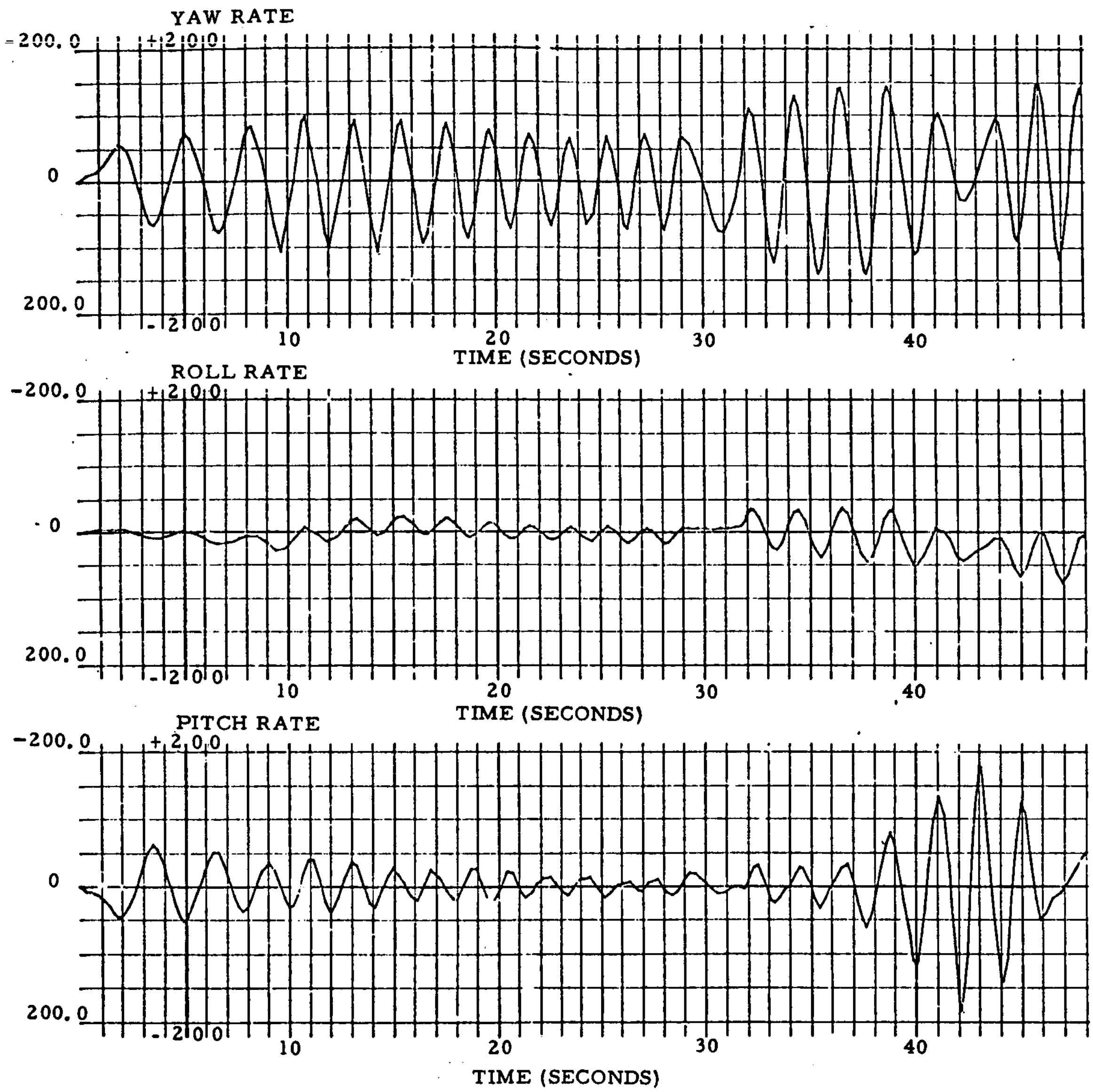

Figure 4-4. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-4

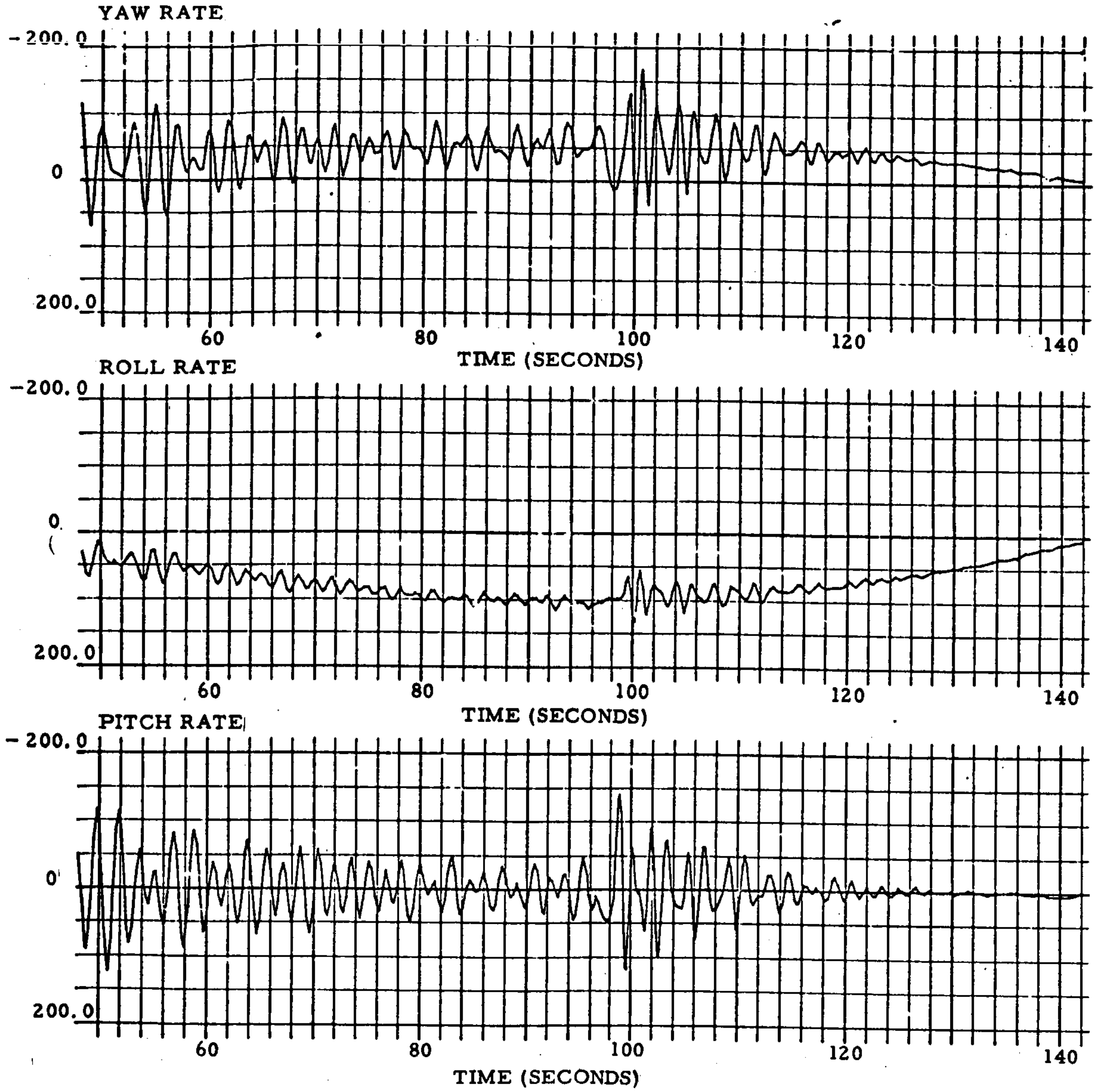

Figure 4-5. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-4

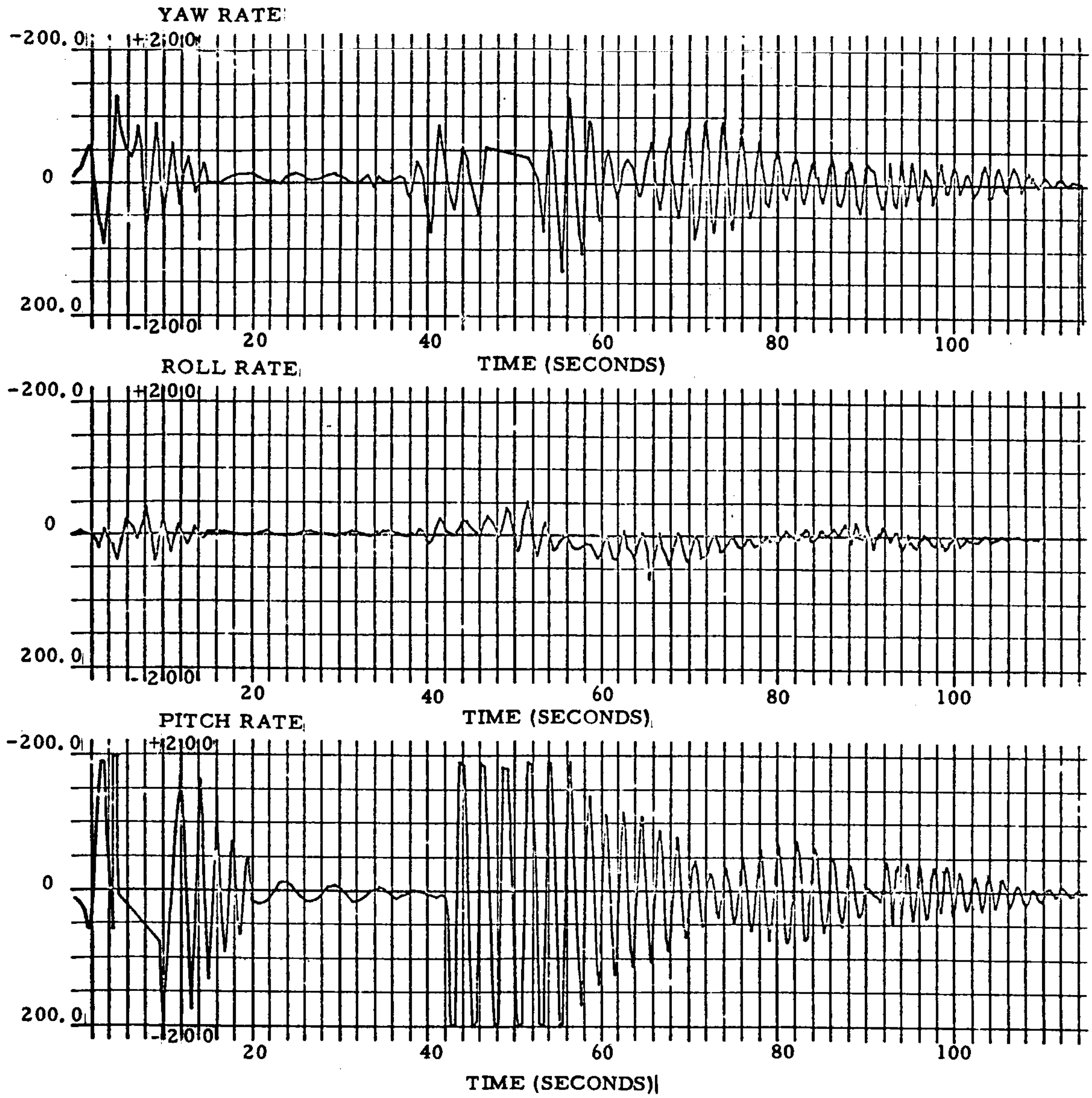

Figure 4-6. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-5

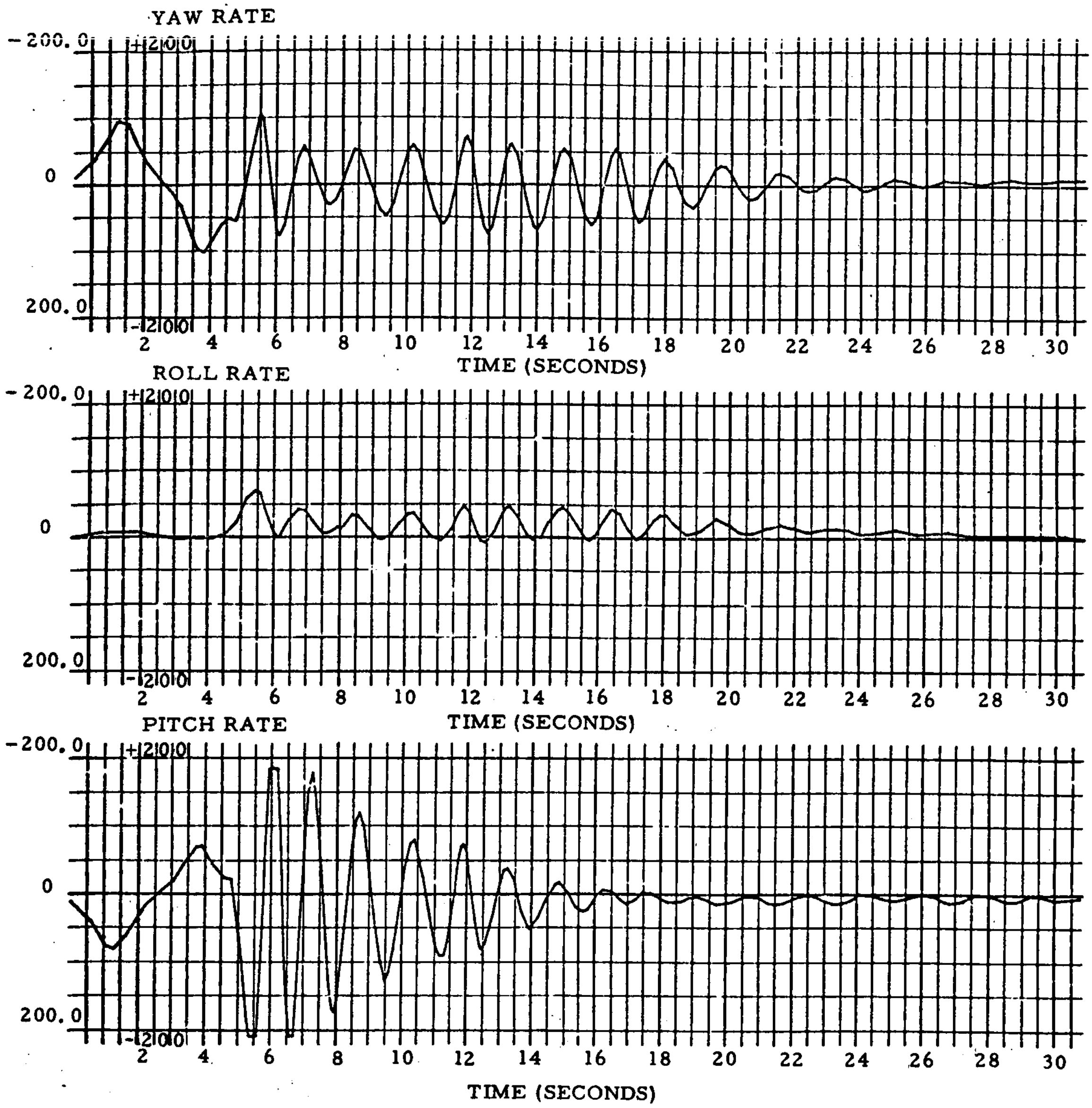

Figure 4-7. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-6

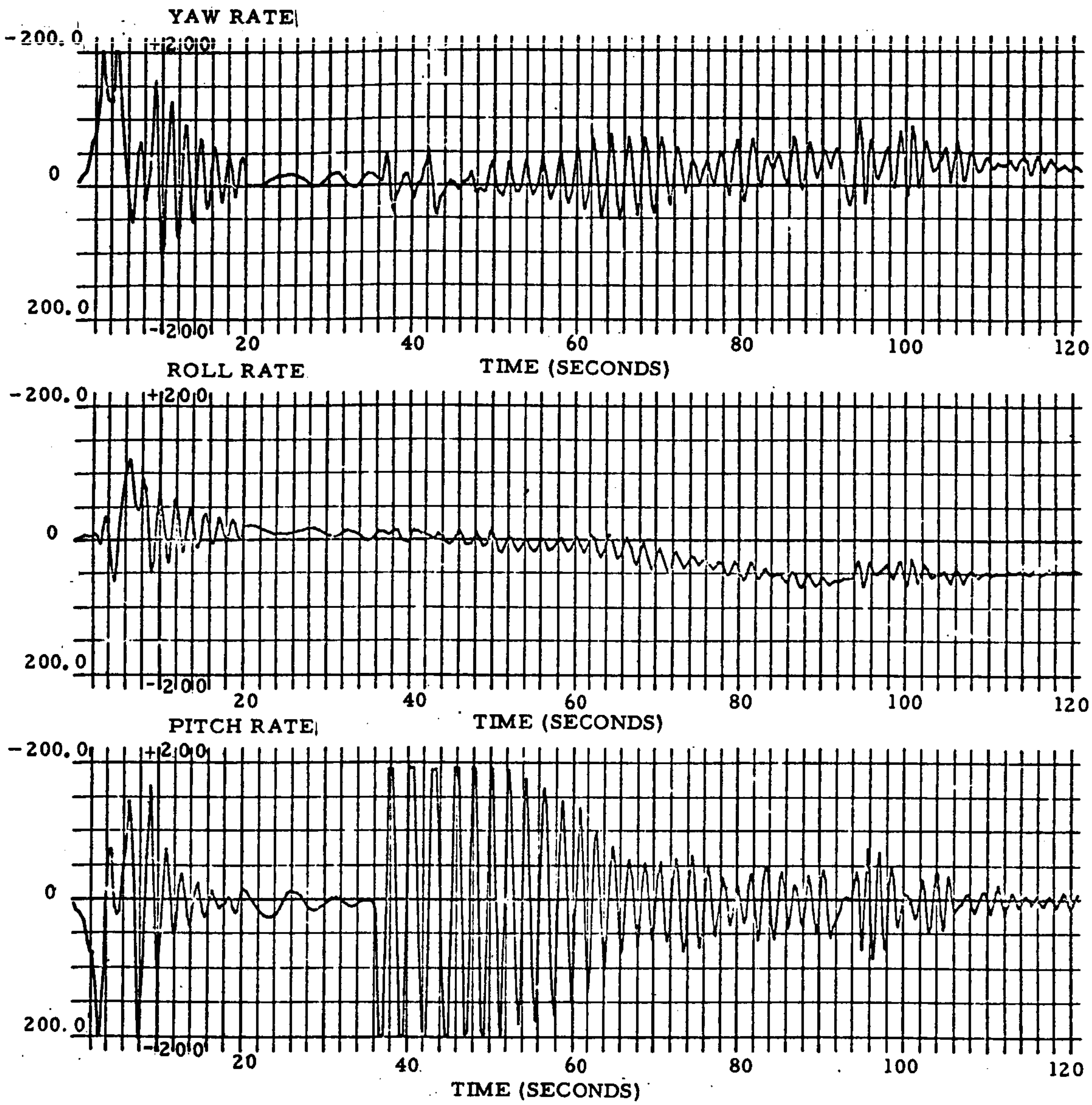

Figure 4-8. Yaw, Pitch, Roll Rates vs Time - Drop Test 85-7

Test 85-1 utilizied two drogue parachutes whereas Tests 85-3 and 85-4 had only one drogue. Therefore, as expected, its vehicle oscillations were less than during the other tests at drogue disconnect and closer simulation of spacecraft conditions.

High altitude abort Tests 85-5 and 85-7 both were very stable in the apex forward attitude during the free fall mode (over 15 seconds) just prior to drogue mortar fire. At reefed inflation of the drogue (both tests), the vehicle was righted to the normal attitude causing violent oscillations that were quickly damped by the single drogue. The roll rate during Test 85-7 persisted through the main parachute phase causing the metal risers to wrap up.

Tests 85-2 and 85-6 simulate the pad abort conditions. Test 85-2 utilized two-drogues for a short time (12 seconds) for actual pad abort. Test 85-6 had only main parachutes for drogue by-pass condition. The oscillations were fairly large during the short drogue phase of Test 85-2 but were damped. After main parachute inflation the oscillations were high but very quickly damped. Test 85-6 oscillations were large at the initiation of the main parachute phase, but were sufficiently damped before they were full open.

The vehicle oscillation for all tests were usually nominal during all phases of operation and generally as predicted by computer analysis. The vehicle was very stable in the apex forward condition during free fall. Two drogue operation usually produced smaller roll oscillation than when only one drogue was utilized.

4.3 PARACHUTE DESIGN ENVELOPES

The drogue and main parachute design envelopes are shown in Figure 4-9. The drogue parachute envelope specifies the entry and abort conditions at drogue mortar fire. The main parachute envelope specifies the conditions at pilot mortar fire.

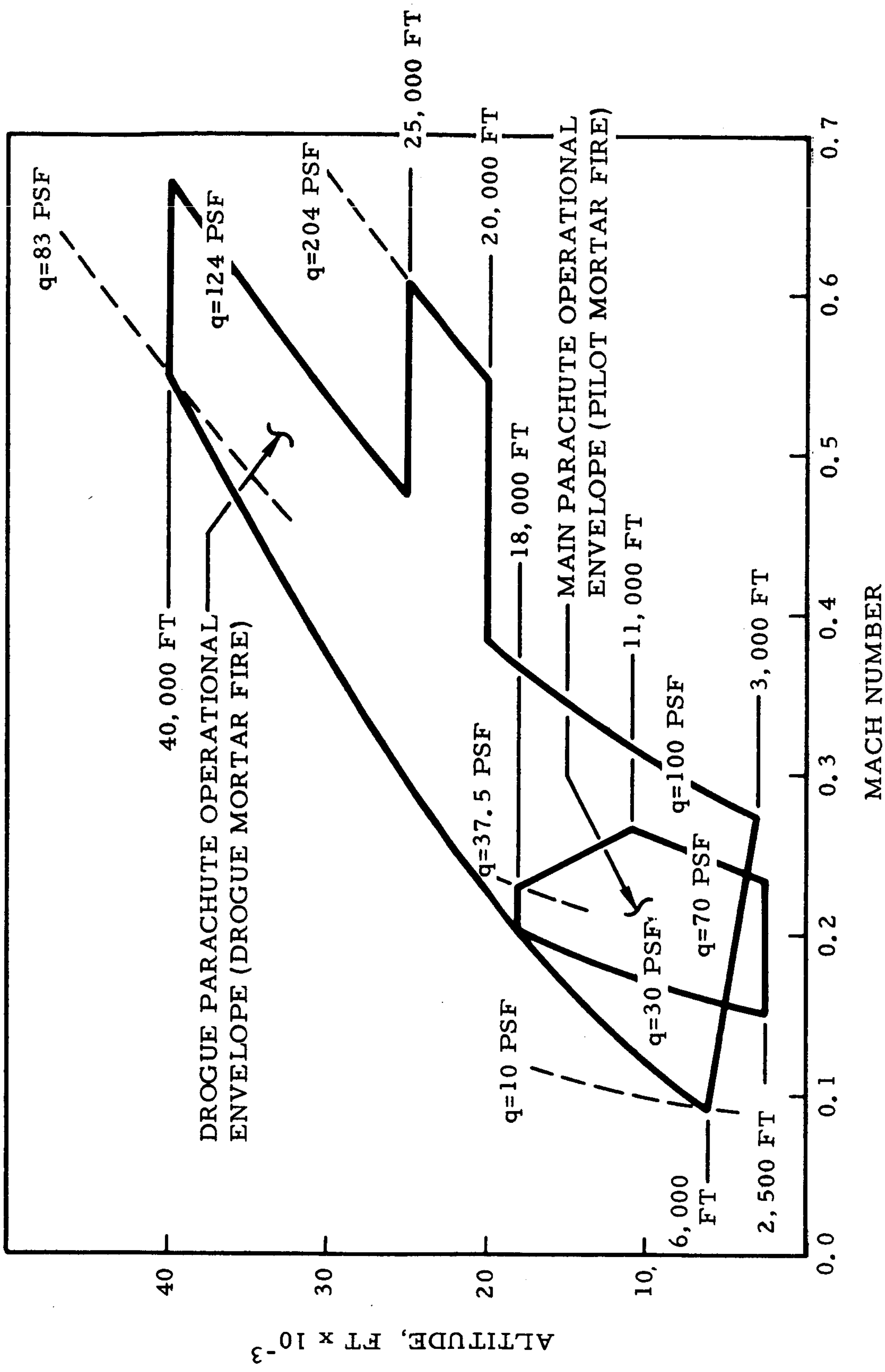

Figure 4-9. Parachute Design Envelopes

Figures 4-10 and 4-11 show the conditions achieved in the qualification tests relative to the design envelopes. Tests 85-1, 85-3 and 85-4 simulate a normal entry flight mode; Tests 85-2 and 85-6 simulate pad abort and Tests 85-5 and 85-7 simulate high altitude abort.

Entry Tests 85-3 and 85-4 were similar in that only one drogue parachute was used. Test 85-4 was the only test of the series conducted assuming a 500 pound overload condition or a nominal recovery weight of 13,500 pounds. The dynamic pressure at drogue mortar fire for Test 85-3 (q = 115) approached that of design or 124 psf. For both tests, the dynamic pressure at pilot mortar fire, at about 4400 feet altitude, was between 64 and 65 psf. This corresponds to a dynamic pressure of about 67 psf for a 13,000 pound recovery weight and a typical pilot mortar fire altitude of about 10,000 feet. Entry Test 85-1 was initiated at about the same dynamic pressure as 85-4, but at a slightly lower altitude. The two drogue parachute used permitted the test vehicle to achieve representative spacecraft altitude and Mach number conditions at pilot mortar fire.

Tests 85-2 and 85-6 simulate pad abort conditions where recovery system initiation occurs at a time when the command module flight path angle is nearer horizontal than vertical. For both tests, recovery system initiation occurred at about 10,000 feet altitude. Test 85-2 utilized two drogues that operated as they would in an actual pad abort or for about 12 seconds. For Test 85-6 the drogues were assumed by-passed; the main parachutes were deployed by the pilot parachutes at a dynamic pressure of 92.3 psf or somewhat above maximum dynamic pressure requirements.

Both Tests 85-5 and 85-7 simulated high altitude abort, high dynamic pressure, one-drogue operational recovery conditions. For both test, the altitude-Mach number conditions achieved at pilot mortar fire were about the same as those achieved for Tests 85-3 and 85-4 which also utilized one drogue.

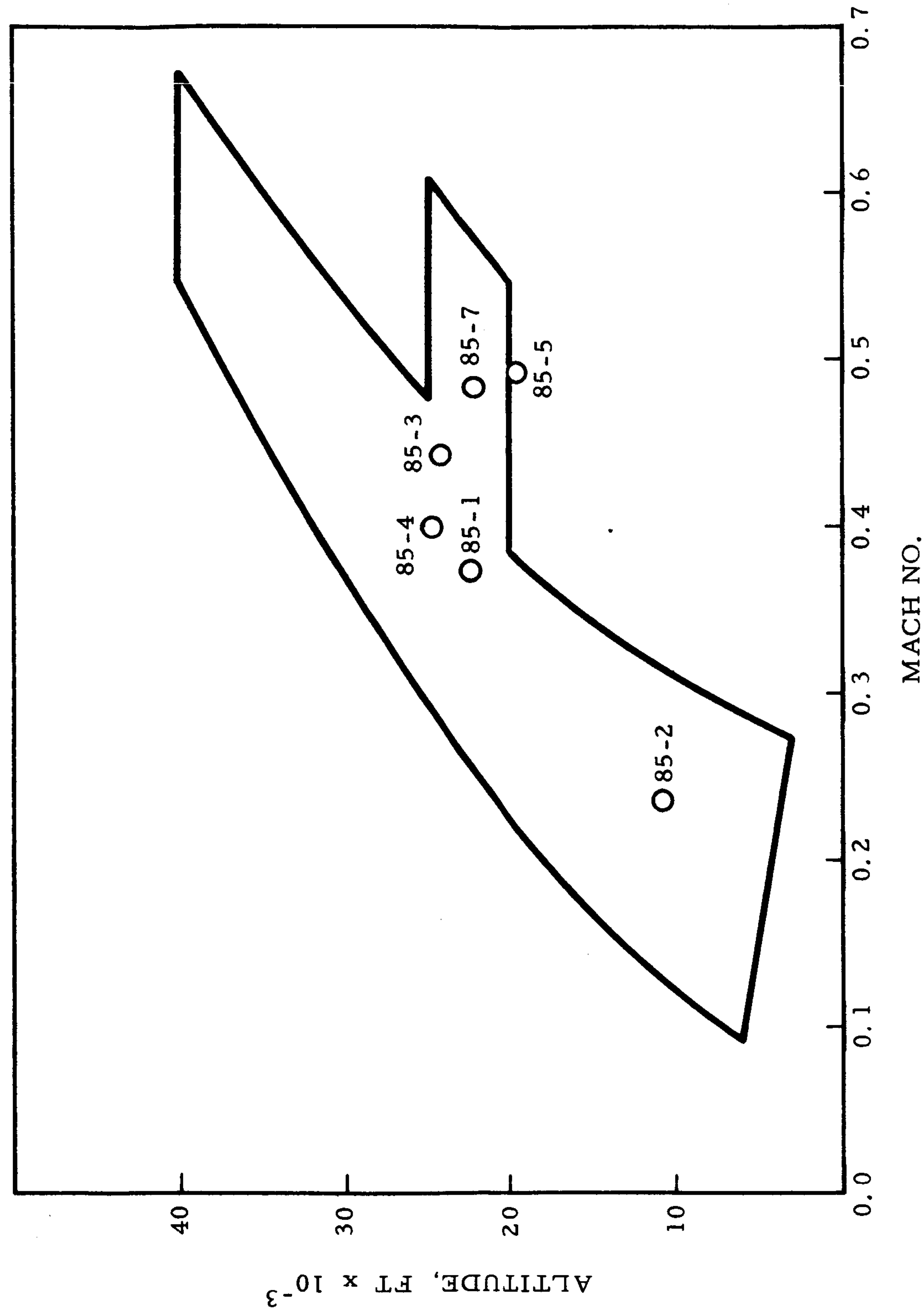

Figure 4-10. Test Points at Drogue Chute Deployment

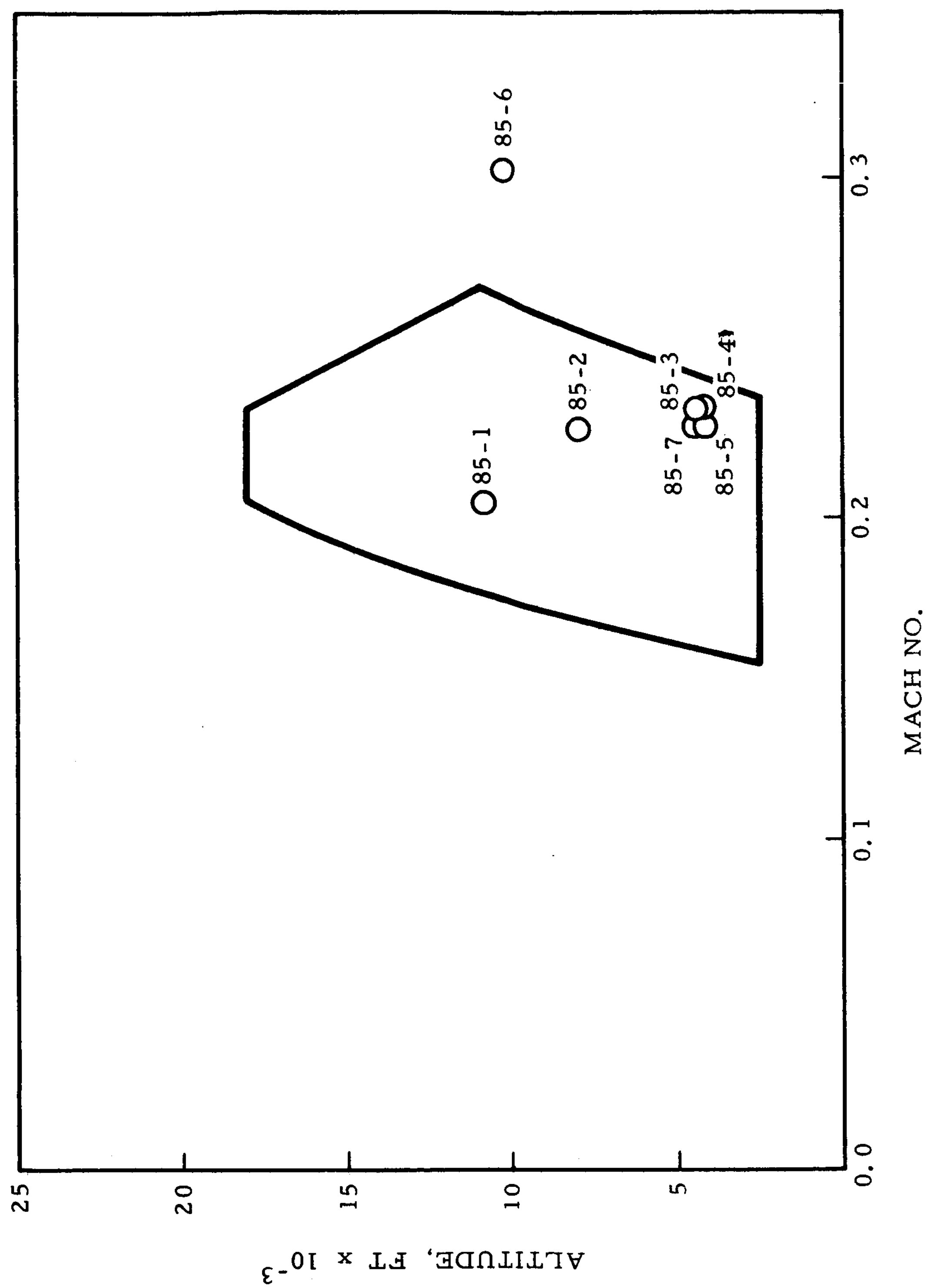

Figure 4-11. Test Points at Main Chute Deployment

4.4 MAIN PARACHUTE DEPLOYMENT CHARACTERISTICS

The time interval for main parachute deployment is defined as the increment of time from pilot parachute mortar fire to main parachute line stretch. This time consists of two distinct intervals; first, the time to deploy and inflate the pilot parachute, and second, the time necessary for the pilot parachute to extract the main parachute pack and deploy the main parachute to line stretch. The total time to deploy each of the pilot and main parachutes as a function of dynamic pressure for the 85 Series drop tests are shown in Figures 4-12 and 4-13.

Figure 4-12 shows that the time from pilot mortar fire to lead pilot parachute full open varies from 0.60 to 0.75 seconds. The greatest differential time from lead pilot parachute full open to lag parachute full open for any of the drop tests was 0.35 seconds. The values for pilot mortar fire to pilot parachute full open are within the corresponding values measured for the Apollo Block I and Block II Qualification Drop Tests, despite the 0.75 lb increase in weight for the pilot pack assembly. The 0.35 second value for differential time from lead pilot parachute full open to lag parachute full open was somewhat larger than the 0.23 second interval encountered in Block II. Although larger, this value does not create any problems.

Figure 4-13 shows the time to deploy each of the main parachutes. The time from pilot mortar fire to main parachute line stretch for lead parachutes varies from 1.69 to 2.20 seconds. These times compare very favorably with those obtained in Block I and Block II. The time from lead parachute line stretch to lag parachute line stretch (Δt) for all drops did not exceed 0.24 seconds. All but two drop tests had Δt's less than 0.18 seconds. These values compare favorably with the Δt of 0.2 seconds used when computing loads under ideal vehicle pitch rate-attitude conditions at drogue disconnect. However, the main parachute first stage design load is based on a Δt of 0.8 seconds. This values assumes adverse disconnect conditions and results in main parachute entrapment.

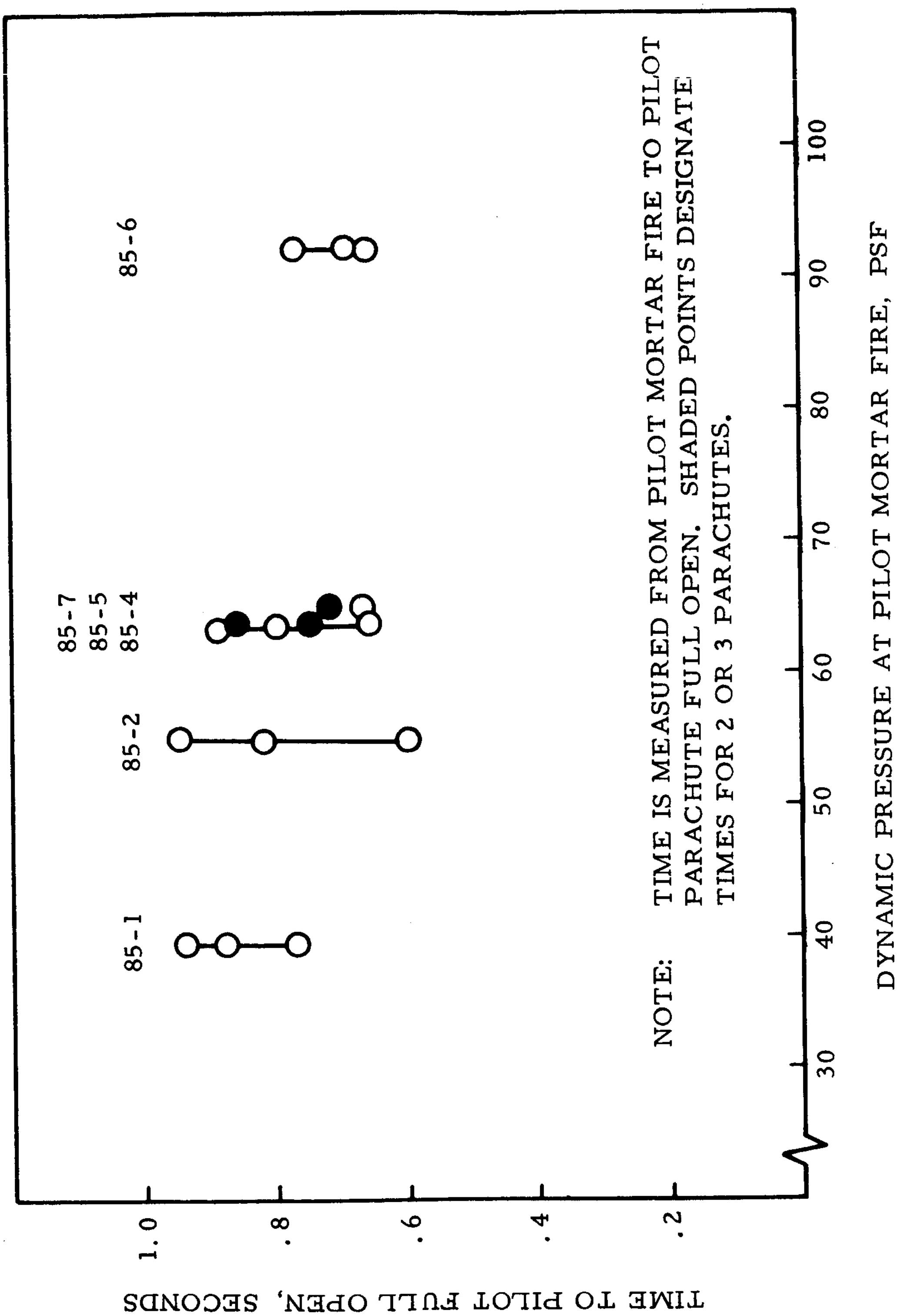

Figure 4-12. Variation in Pilot Chute Deployment Time With Dynamic Pressure

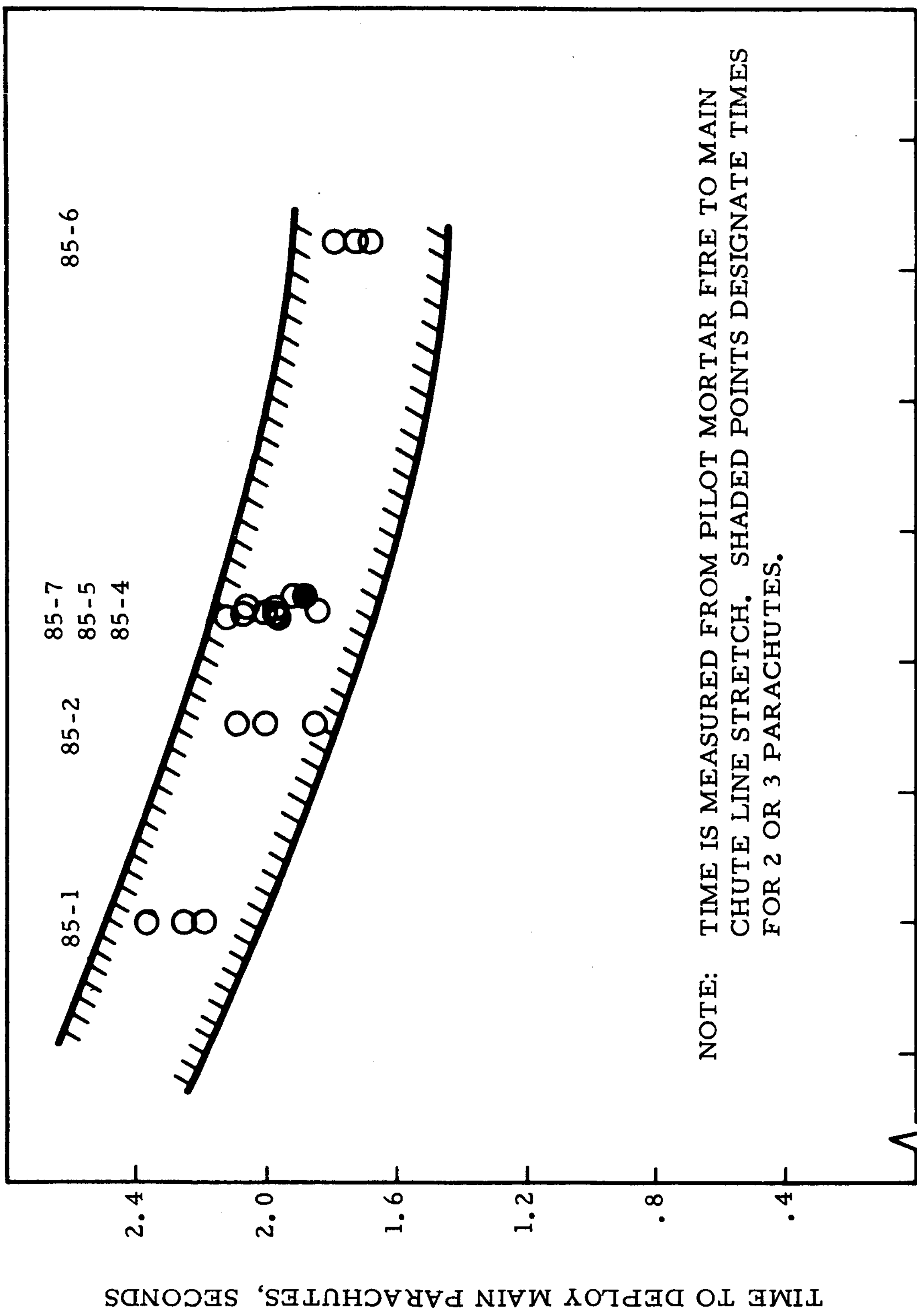

Figure 4-13. Variation in Main Parachute Deployment Time With Dynamic Pressure

4.5 DROGUE PARACHUTE DEPLOYMENT CHARACTERISTICS

The time interval for drogue parachute deployment is defined as the increment of time from drogue mortar fire to drogue line stretch. The time required to deploy the drogue parachutes is shown in Figure 4-14 as a function of dynamic pressure. The time for deployment of the lead parachute varies from 0.56 to 0.84 seconds. From Figure 4-14 it is obvious the $\Delta t = 0.84$ is not representative of the region of Δt's determined by the remaining drop tests. A possible explanation for the large Δt is the fact that the vehicle was almost apex forward at drogue mortar fire, thus requiring the drogue to swing through a 180° arc before line stretch could occur.

A Δt of 0.6 of a second is used for the design case where the dynamic pressure is 204 psf. From the band of points obtained from the 85 Series drop tests, the value of 0.6 of a second appears to be a little long or somewhat conservative.

4.6 STEADY STATE RATE OF DESCENT PERFORMANCE

Vehicle descent velocity was measured during all qualification drop tests by the Askania cinetheodolite stations. The data, as received, was corrected to mean sea level standard day conditions. Figures 4-15 through 4-21 present this data for vehicle altitudes below 2,000 feet.* Drop Test 85-7 was conducted using two main parachutes. The other six tests used three main parachutes. All tests, except 85-4, were conducted to simulate a total vehicle weight without apex cover of 13,000 pounds or a descent weight with drogue parachutes released of about 12,920 pounds. Test 85-4 was conducted to simulate a vehicle weight without apex cover of 13,500 pounds. The descent weight with drogues released would be about 13,420 pounds. The actual descent weight for all tests was within one half of one percent of that desired.

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* Accuracy of this data is estimated to be $\pm 5\%$.

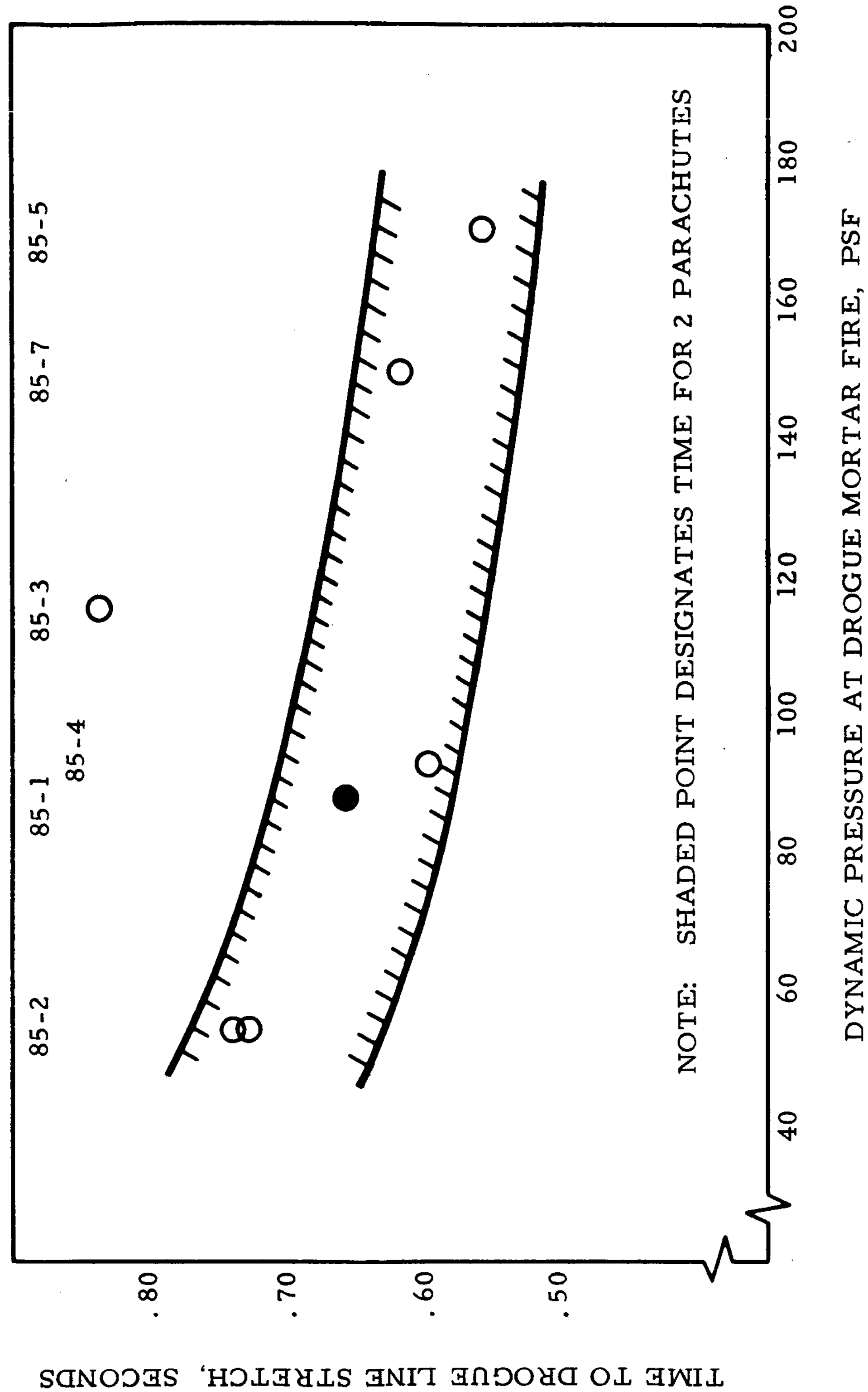

Figure 4-14. Variation in Drogue Parachute Deployment Time With Dynamic Pressure

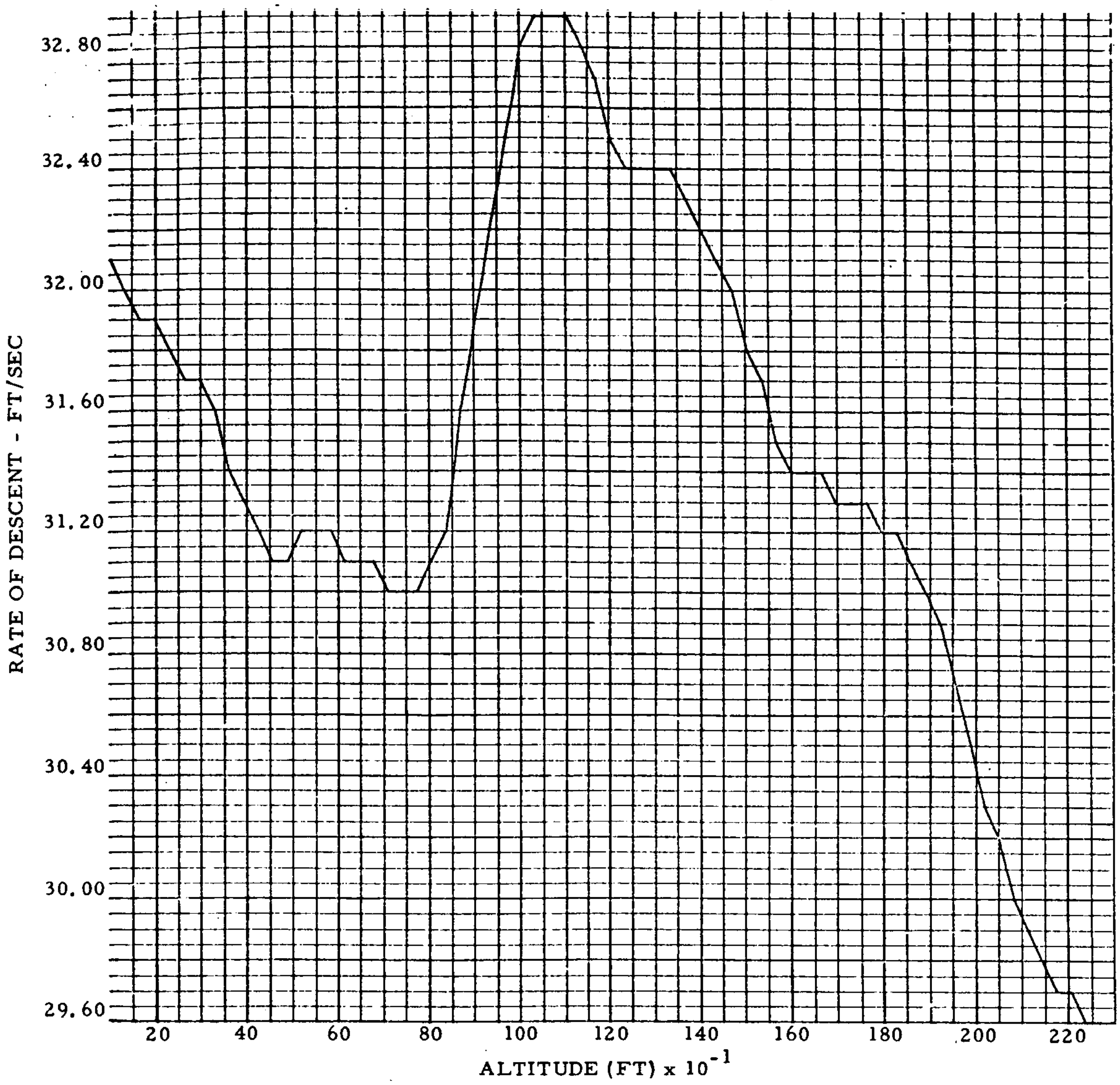

Figure 4-15. Mean Sea Level Standard Day, Rate of Descent - Test 85-1

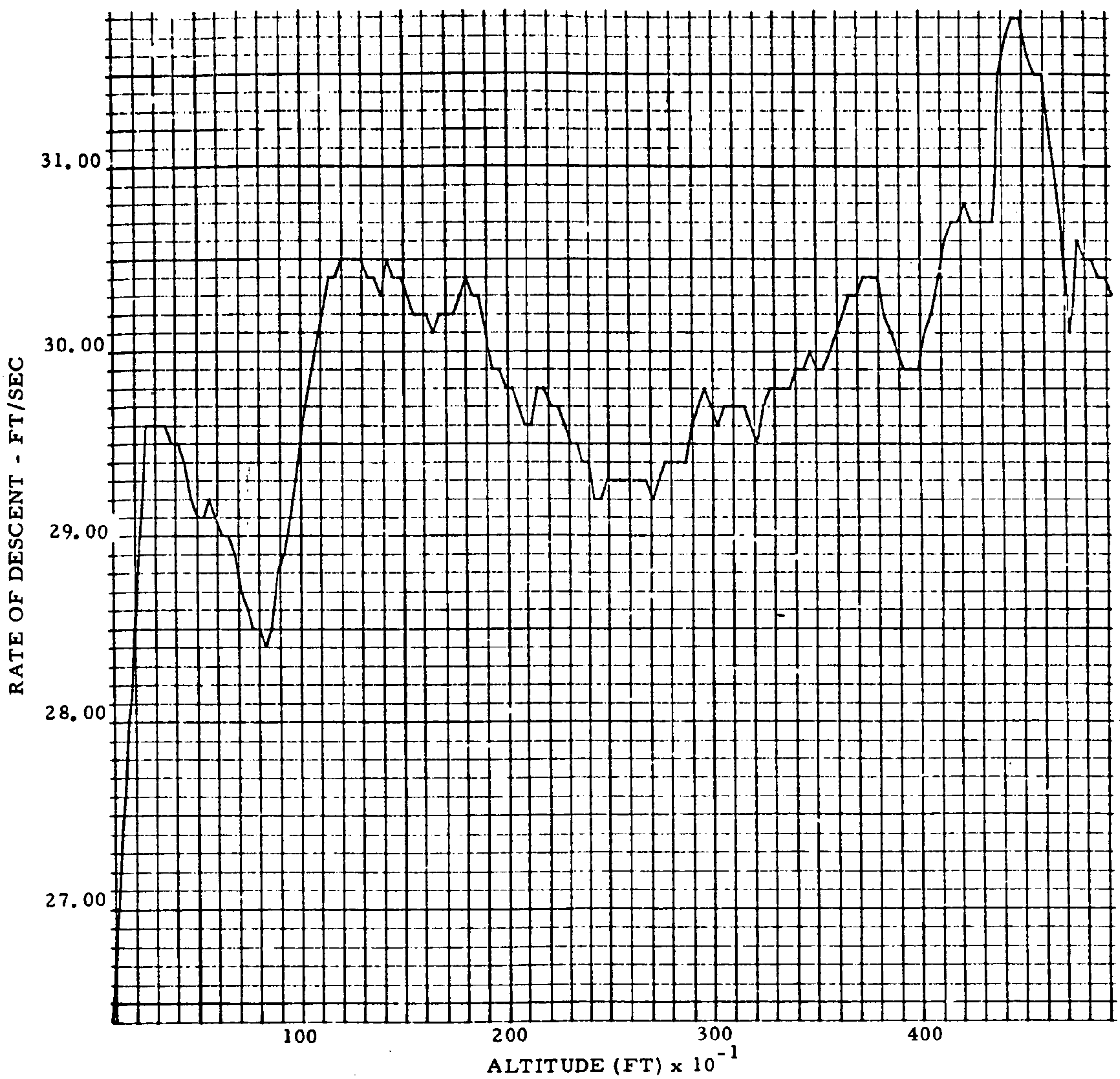

Figure 4-16. Mean Sea Level Standard Day, Rate of Descent - Test 85-2

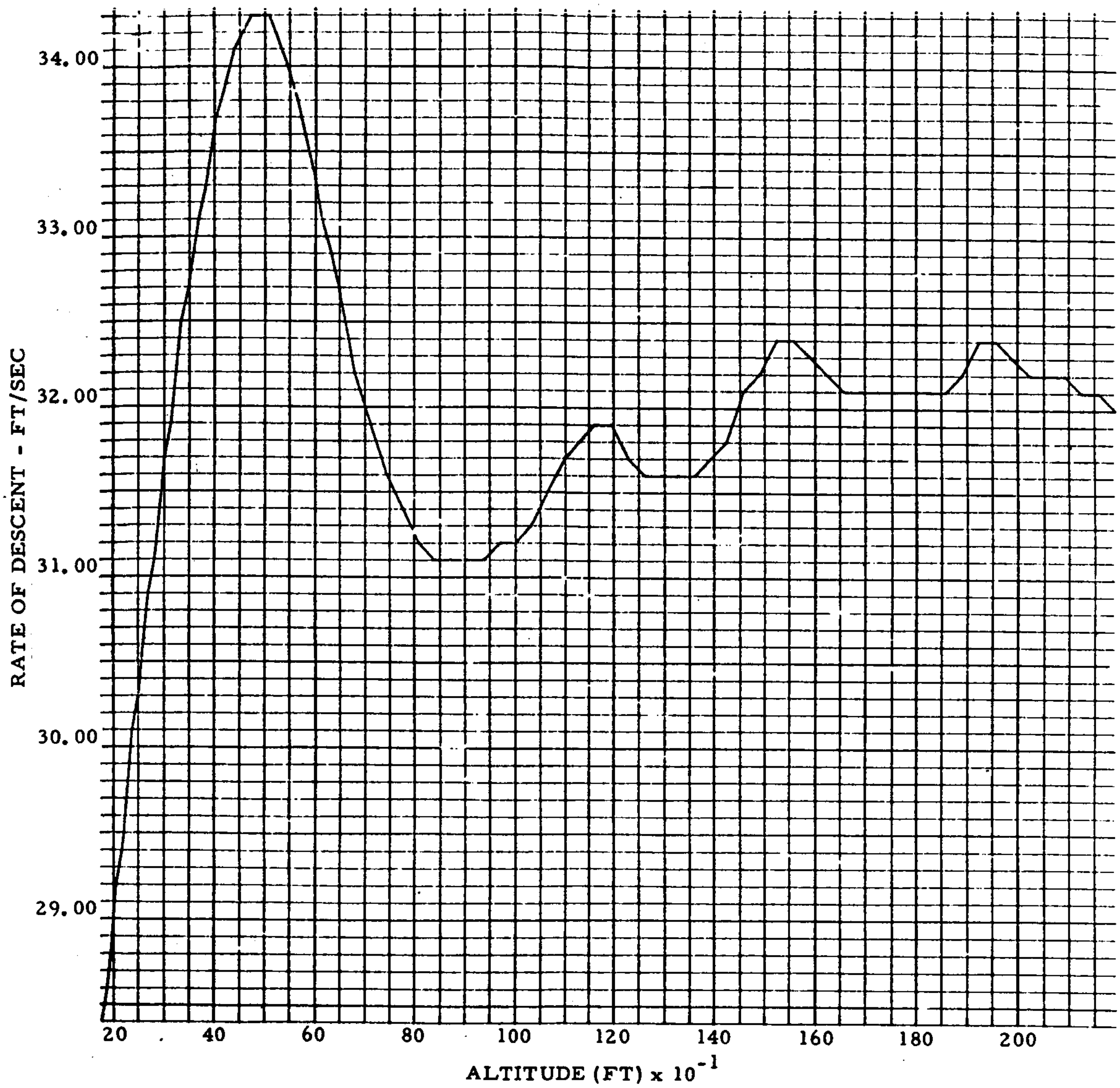

Figure 4-17. Mean Sea Level Standard Day, Rate of Descent - Test 85-3

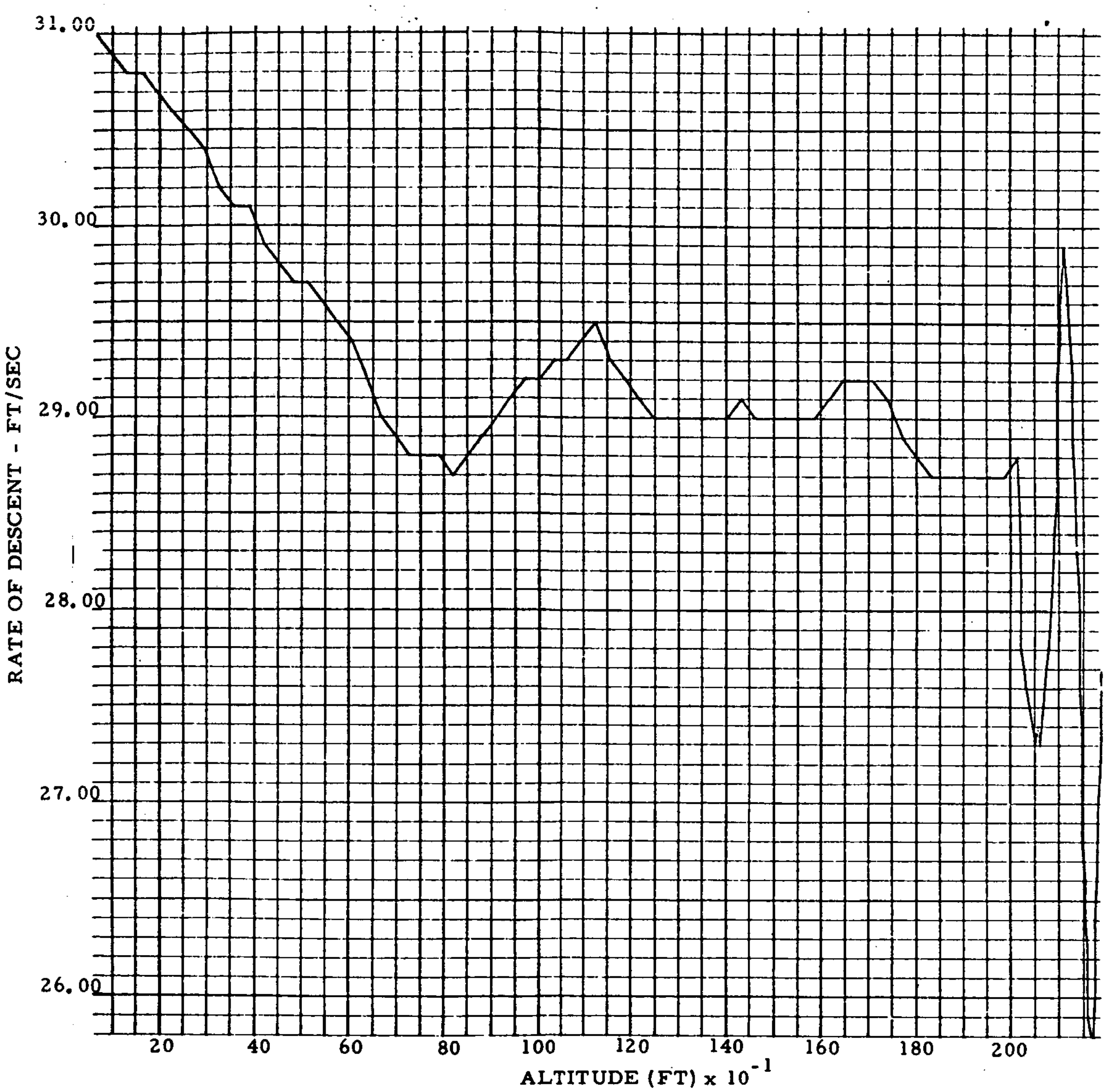

Figure 4-18. Mean Sea Level Standard Day, Rate of Descent - Test 85-4

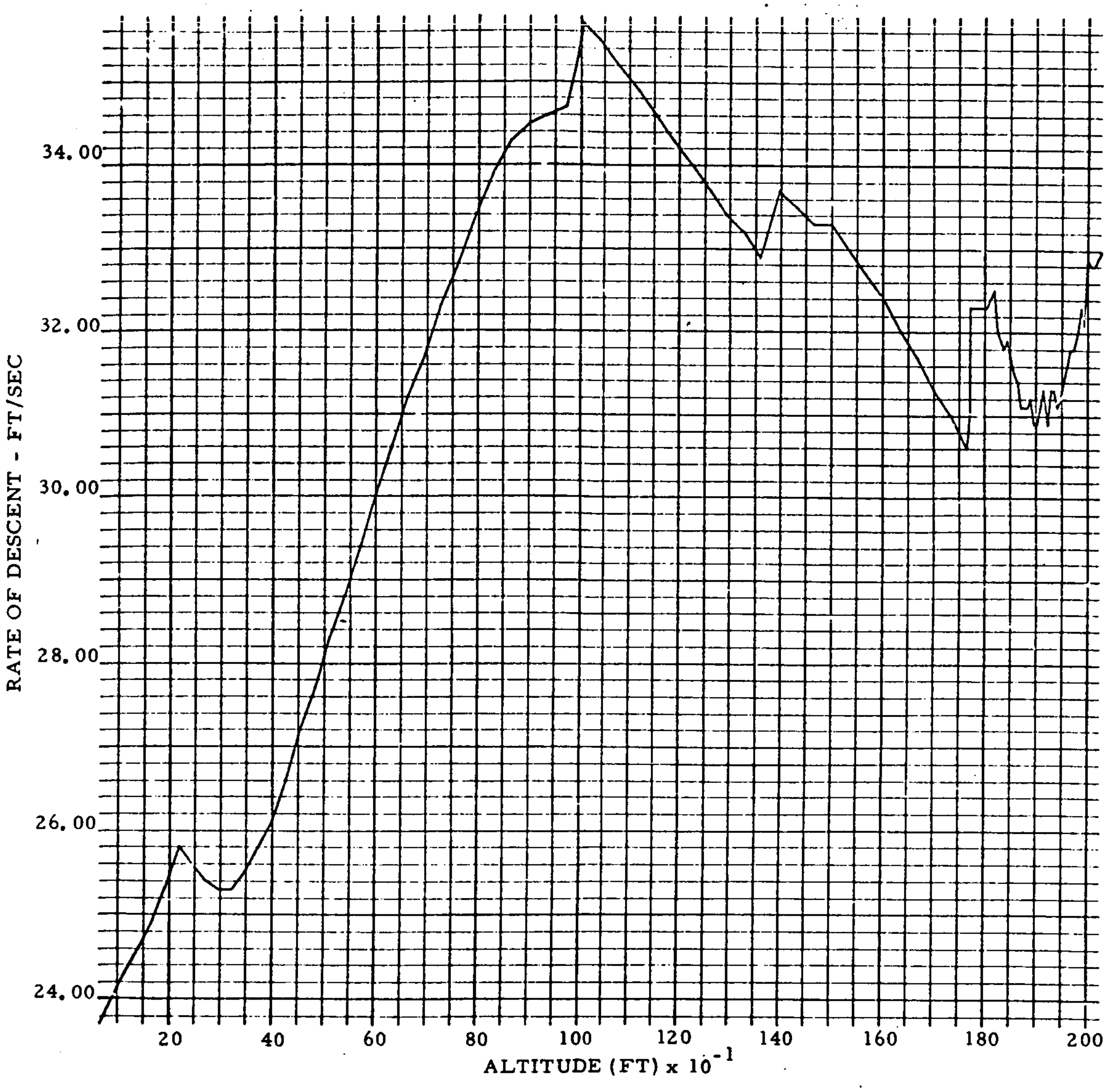

Figure 4-19. Mean Sea Level Standard Day, Rate of Descent - Test 85-5

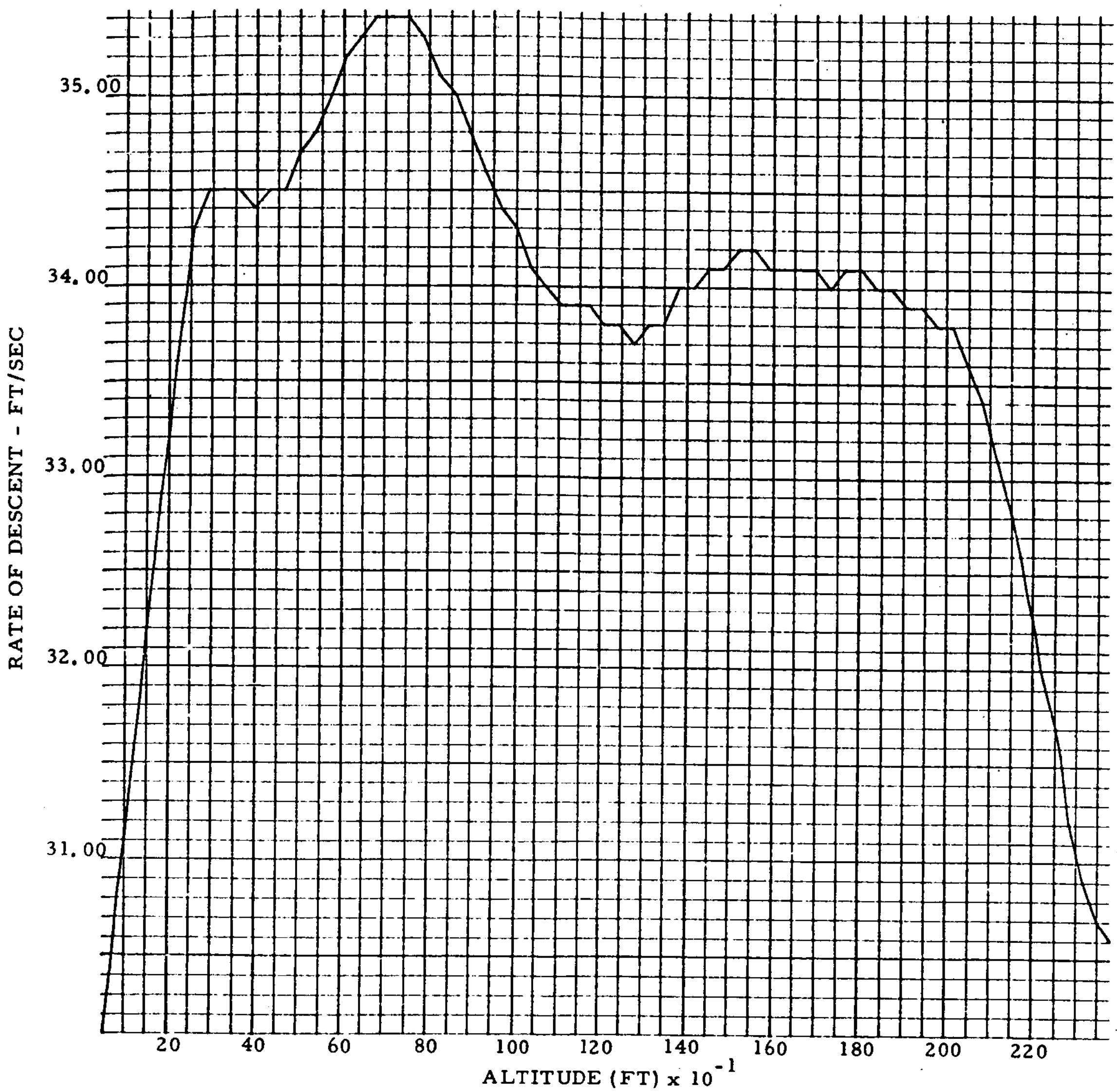

Figure 4-20. Mean Sea Level Standard Day, Rate of Descent - Test 85-6

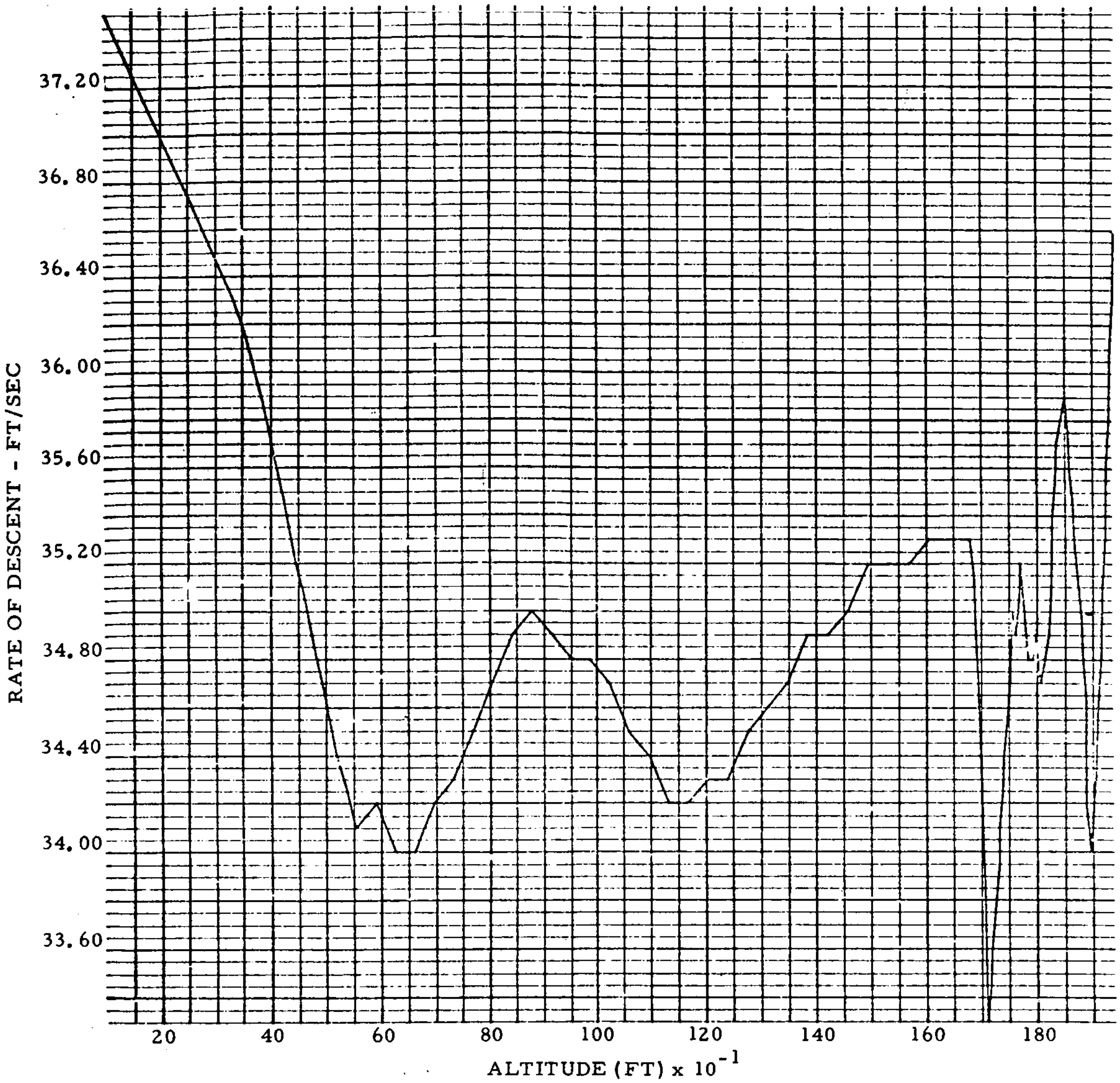

Figure 4-21. Mean Sea Level Standard Day, Rate of Descent - Test 85-7

Table 4-4 presents mean, minimum and maximum rate of descent values for each test. All values were obtained from Figures 4-15 through 4-21 at altitudes between 500 and 2,000 feet and then adjusted to a standard descent weight of 12,920 pounds.

For the three parachute tests, the mean descent rate varies from 28.4 to 34.2 ft/sec; the average is 31.4 ft/sec. For these tests, maximum and minimum values are 35.4 and 28 ft/sec, respectively. The mean descent rate for Test 85-7 (two main parachutes) was 34.7 ft/sec; the maximum was 35.2 ft/sec. The variation in mean rate of descent, considering all tests, is about 3 ft/sec. This difference is attributed to slightly varying drag characteristics of the main parachute cluster, thermal induced air currents and inaccuracies in Askania data reduction.

The maximum descent rate for Test 85-7 is well within the two main parachute limit of 38 ft/sec stated in the NR Specification ME 623-0006. The test indicates that the drag area provided by the two parachutes was about 80 percent of the drag provided by the average three parachute tests. If each parachute provided the same drag area, two parachutes should provide approximately two-thirds the drag of three parachutes. Assuming that the actual average two to three parachute drag area ratio is nearer two-thirds than 0.8, the mean rate of descent measured during Test 85-7 is not average, but on the low side. Based on a three parachute average rate of descent of 31.4 ft/sec, and a two to three parachute drag area ratio of two-thirds, the average rate of descent for two parachutes should be about 38 ft/sec. The actual average rate of descent is probably higher than the 34.7 ft/sec measured, but lower than the 38 ft/sec computed.

Review of all Block I and II three parachute rate of descent data shows that the average measured rate for all tests was 26.9 ft/sec. If this rate were adjusted to a 12,920 pound recovery weight by multiplying the square root of

Table 4-4. Mean Sea Level Rate of Descent (R/D) for a 13,000 Pound Vehicle

Test	Descent Weight (lbs)	Mean R/D (ft/sec)	Minimum R/D (ft/sec)	Maximum R/D (ft/sec)
85-1	12,936	31.7	30.4	32.9
85-2	12,958	29.3	28.4	30.5
85-3	12,965	31.9	31.0	34.2
85-4	13,442	28.4	28.1	29.1
85-5	12,941	32.8	28.0	35.4
85-6	12,988	34.2	33.6	35.3
85-7	12,950	34.7	34.0	35.2

the weight ratio, the rate of descent would be about 29.3 ft/sec. Since this value is about two ft/sec less than the average measured during the 85 Series tests, it is possible that 85 Series, three-parachute rate of descent values are high. Based on a three parachute average rate of descent of 29.3 ft/sec and a two-thirds drag area ratio, the average rate of descent for two parachutes would be 36.3 ft/sec.

4.7 DROGUE LOADS AND DRAG AREAS

Two methods have been established for obtaining actual drag areas. The first method is that of dividing the recorded force outputs on the parachute by the corresponding time value of dynamic pressure. In doing this, two possible sources of error are introduced: (1) the degree of accuracy of the loads and (2) the degree of accuracy of dynamic pressure from Askania. The second method is to compute the dynamic pressure time history for various drag areas to simulate the dynamic pressure from Askania. This method is highly dependent upon the accuracy of the Askania information; however, Askania is the only source of error. The most undesirable feature of this method is the problem of separating the vehicle drag from the parachute drag. The results of the two methods are presented in Table 4-5. It is obvious that the drogue reefed drag values obtained by dividing force by the corresponding dynamic pressures are inconsistent and of poor quality. However, taking an average of those values obtained, does yield a drag area of 61 ft^2. Drop Tests 85-1 and 85-2 utilized two drogue parachutes. The resulting vehicle oscillations during the reefed drogue phase were nominal. Upon analysis of the vehicle oscillations and the associated drag areas at the various attitudes, a value of 90 ft^2 appears to be realistic for an average value of vehicle drag throughout the drogue reefed interval. Subtracting this value from the total drag area, yields values for the two reefed drogues of 133 ft^2 for 85-1 and 129 ft^2 for 85-2. These two averaged together, yield a value of 65.5 ft^2 compared to 65 ft^2 predicted.

Test	Stage	Parachute	Dynamic Pressure (DLS or Disreef) Pred.	Dynamic Pressure (DLS or Disreef) Act.	Predicted Load	Actual Load (F) Link A	Actual Load (F) Link B	Actual Load (F) Parachute (ave.)	Dynamic Pressure at Peak Load
								(6 + 7)/2	
85-1	F_R	+Y	93.9	89.9	8,000	6,200	8,000	7,100	89.3
		-Y	93.9	89.9	8,000	7,100	*	7,100	87.3
	F_o	+Y	61.9	64.5	8,450	7,700	8,300	8,000	63.8
		-Y	61.9	64.6	8,450	9,550	*	9,550	64.5
85-3	F_R	+Y	106.5	121.0	9,080	8,750	*	8,750	123.2
		-Y							
	F_o	+Y	86.6	109	11,800	14,500	*	14,500	109
		-Y							
85-2	F_R	+Y	54.3	58.3	4,620	5,330	4,780	5,055	62.1
		-Y	54.3	58.3	4,620	*	3,180	3,180	62.5
	F_o	+Y	55.4	58.4	7,550	9,000	8,300	8,650	58.0
		-Y	55.4	57.6	7,550	*	5,710	5,710	57.2
85-5	F_R	+Y	175.8	168.8	15,000	12,680	10,430	11,555	168.01
		-Y							
	F_o	+Y	94.4	107.8	12,900	*	10,969	10,969	107.68
		-Y							
85-4	F_R	-Y	106.5	95.0	9,080	9,610	*	9,610	97.2
	F_o	-Y	86.6	98.9	11,800	14,630	*	14,630	98.9
85-7	F_R	+Y	153.3	150.5	13,625	*	*	*	*
		-Y							
	F_o	+Y	109.2	109.0	14,880	*	*	*	*
		-Y							
1	2a	2b	3	4	5	6	7	8	9

FOLD-OUT #1

Drogue Reefing 42.8 Percent. Reefing Line Length 266 I

*Data not available.

(C_DS) Peak $= F/q$	Parachute Average Drag Area		Total Drag Area (from Comp.)	Drag Area of Vehicle	C_K	$C_K = \frac{(C_DS)\text{ Peak}}{(C_DS)\text{ Anal.}}$	$C_K = \frac{(C_DS)\text{ Peak}}{(C_DS)\text{ Act.}}$	C_f
	Pred.	Act.			Pred.			
8 / 9				13 - 12		10 / 11	10 / 12	
79.5	65	55	223	*	1.31	1.22	1.45	-
81.3	65	70			1.31	1.25	1.16	1.27
125.4	109	96	338	*	1.25	1.15	1.31	-
148.1	109	130			1.25	1.36	1.14	1.23
71.0	65	57	133	76	1.31	1.09	1.29	1.25
133.0	109	100	209	109	1.25	1.22	1.33	1.26
81.4	65	73.5	219	105.5	1.31	1.25	1.11	1.20
50.9	65	40			1.31	0.78	1.27	1.14
149.1	109	118	260	52	1.25	1.37	1.26	1.14
99.8	109	90			1.25	0.92	1.11	1.10
68.84	65	47	141	94	1.31	1.06	1.46	1.39
101.86	109	82	209	127	1.25	.93	1.24	1.26
98.7	65	84	148	64	1.31	1.52	1.18	1.20
147.9	109	134	214	80	1.25	1.35	1.10	1.19
*	65	*	143	*	1.31	*	*	*
*	109	*	215	*	1.25	*	*	*
10	11	12	13	14	15	16	17	18

nches. Overinflation Line Length 396 Inches.

FOLD-OUT #2

Table 4-5. Drogue Parachute Data - 85 Series Tests

The same two methods are applied to the full open drag area of the drogue. The full open drag areas obtained by dividing force by dynamic pressure are inconsistent and of poor quality as were the reefed drag areas. An average of those values obtained does yield an average drag area of 107 ft^2. The results of simulating dynamic pressure decay appear to be much more consistent. In Drop Test 85-1, vehicle oscillations were small because two drogues were used and the dynamic pressure was relatively low at drogue line stretch. Because the vehicle was very stable at drogue disconnect, a vehicle drag area of 110 ft^2 appears to be realistic. Subtracting this value from the total drag area needed to simulate the dynamic pressure at drogue disconnect yields a drag area of 114 ft^2 for each parachute. Drop Test 85-2 was not analyzed because of its very short (two seconds) time at full open before disconnect. The remaining four drop tests were analyzed in the same manner. During each test one drogue was used, and moderate vehicle oscillations occurred during the full open drogue interval. Based on the vehicle aerodynamic coefficients at Mach 0.25, the vehicle average drag area following drogue disreef is about 100 ft^2.

Because of the nature in which the drogue loads were obtained, (instrumented risers) the quality of the loads is not as good as desired. The inconsistencies are obvious when drag areas are obtained by dividing the forces by dynamic pressure. The range of values obtained for C_K on lead parachutes vary from 1.06 to 1.52 for F_R and from 0.94 to 1.37 for F_o. The 1.52 value is felt to be high and not representative. These are much larger ranges than experienced when using load links in the development tests. However, an average value of C_K for F_R appears to be 1.23. Thus, the design case value of 1.40 appears to be very conservative. The same condition applies to the C_K factor for F_o. The average value obtained from the 85 Series is 1.25 compared to the 1.31 value used in design.

Drogue loads are dependent upon C_K, q and C_DS. Assuming "q" is established from the design case, and that the drag areas used appear to be representative, the loads calculated based on the design C_K factors should be conservative.

4.8 MAIN PARACHUTE LOADS AND DRAG AREAS

Table 4-6 presents the basic loads data measured during the Series 85 Drop Tests. Columns 3, 4, and 5 show the time to main parachute line stretch (MCLS) or disreef, delta times from pilot mortar fire to MCLS, and delta times from MCLS to disreef for each stage of each parachute. Columns 6 and 7 show the dynamic pressure recorded at pilot mortar fire, MCLS, and at first and second-stage disreef times. Predicted and measured peak loads for each parachute and each parachute stage are shown in Columns 8 through 11. Columns 12 through 15 compare predicted average drag areas with average drag areas computed by dividing measured force by dynamic pressure during the parachute operational interval. Column 16 presents the calculated dynamic pressure at first and second-stage disreef times, assuming that the calculated drag areas listed in Column 15 were attained during the drop tests. Since loads for one or more parachutes were not obtained for Drop Tests 85-2, 85-3 and 85-6, the disreef pressure for these tests could not be calculated.

Total calculated first-stage parachute drag area for Drop Test 85-1, 85-4 and 85-5 where three main parachutes were used is 960, 875 and 845-ft^2. These values compare with a total drag area of 768-ft^2 used during pretest trajectory calculations. For Test 85-7, a total parachute drag area of 460-ft^2 was calculated as compared to 542-ft^2 used during pretest trajectory calculations. The range in calculated drag areas (from test data) appears to be too great to be realistic. Further evidence of this is seen when comparing measured first stage disreef dynamic pressure with the corresponding

1	2a	2b	3	4		5		6		7	
Test	Stage	Para-chute	t_{MCLS} or t_{dis}	Δt PMF to MCLS		Δt MCLS to Disreef		q_{PMF}		q_{MCLS} or $q_{Disreef}$	
85-1				Pred.	Act.	Pred.	Act.	Pred.	Act.	Pred.	Act.
	F_{R_1}	+Y	77.03	1.90	2.26	-	-	41.8	39.4	58.2	56.0
		-Y	77.15	1.90	2.38	-	-	41.8	39.4	58.2	56.3
		+Z	76.97	1.90	2.18	-	-	41.8	39.4	58.2	55.8
	F_{R_2}	+Y	83.16	-	-	6.40	6.13	-	-	17.2	15.2
		-Y	83.45	-	-	6.40	6.30	-	-	17.2	14.5
		+Z	83.25	-	-	6.40	6.30	-	-	17.2	15.0
	F_o	+Y	87.71	-	-	10.6	10.68	-	-	4.2	4.4
		-Y	87.88	-	-	10.6	10.73	-	-	4.2	4.2
		+Z	87.55	-	-	10.6	10.60	-	-	4.2	4.5
85-2	F_{R_1}	+Y	20.81	1.90	1.86	-	-	52.2	55.2	68.4	73.1
		-Y	20.96	1.90	2.01	-	-	52.2	55.2	68.4	73.4
		+Z	21.05	1.90	2.10	-	-	52.2	55.2	68.4	73.3
	F_{R_2}	+Y	27.04	-	-	6.4	6.23	-	-	17.0	13.5
		-Y	26.96	-	-	6.4	6.00	-	-	17.0	13.8
		+Z	27.00	-	-	6.4	5.95	-	-	17.0	13.8
	F_o	+Y	31.14	-	-	10.6	10.33	-	-	4.1	4.3
		-Y	31.24	-	-	10.6	10.28	-	-	4.1	4.2
		+Z	31.88	-	-	10.6	10.33	-	-	4.1	4.1
85-3	F_{R_1}	+Y	94.84	1.90	1.85	-	-	64.1	63.7	80.0	77.5
		-Y	95.06	1.90	2.07	-	-	64.1	63.7	80.0	78.0
		+Z	94.97	1.90	1.98	-	-	64.1	63.7	80.0	77.8
	F_{R_2}	+Y	101.11	-	-	6.4	6.27	-	-	16.9	16.3
		-Y	101.29	-	-	6.4	6.23	-	-	16.9	16.3
		+Z	101.28	-	-	6.4	6.31	-	-	16.9	16.0

Δ ~ Very Poor Results (Questionable)

FOLD-OUT #1

Peak Loads				12	13	14	15	16
Actual				Drag Area				$q_{Disreef}$ (Calculated)
8 Pred.	9 Link A	10 Link B	11 Parachute (ave.)	$(C_DS)_n$ Pred.	$(C_DS)_n$ Link A	Actual Link B	C_DS (ave.)	
			(9 + 10)/2				(13 + 14)/2	
9,090	10,150	8,820	9,485	238	280	230	255	-
-	8,830	9,480	9,155	265	280	280	280	-
7,361	13,050	11,100	12,075	265	450	400	425	-
11,220	7,300	6,440	6,870	972	850	700	775	13.66
-	8,020	7,900	7,960	1,080	1,000	950	975	13.45
10,874	12,770	10,790	11,780	1,080	1,250	1,100	1,175	13.58
9,870	5,550	4,540	5,045	4,200	5,600	4,500	5,050	4.46
-	7,030	6,900	6,965	4,200	5,000	5,000	5,000	4.45
-	11,400	10,290	10,845	4,200	6,700	6,500	6,600	4.48
9,580	-	-	-	238	-	-	-	
-	15,200	12,000	13,600	265	400	350	375	
7,858	11,900	14,500	13,200	265	400	500	450	
10,960	-	-	-	972	-	-	-	
-	12,600	10,000	11,300	1,080	1,400	1,150	1,275	
10,650	11,600	14,400	13,000	1,080	1,300	1,600	1,450	
9,850	-	-	-	4,200	-	-	-	
-	11,610	9,100	10,355	4,200	7,800	6,000	6,900	
-	9,380	11,920	10,650	4,200	6,500	8,400	7,450	
10,330	-	-	-	265	-	-	-	
-	10,200	11,250	10,725	265	Δ	Δ	-	
8,372	-	-	-	238	-	-	-	
10,770	-	-	-	1,080	-	-	-	
-	-	-	-	1,080	Δ	Δ	-	
10,458	-	-	-	972	-	-	-	

FOLD-OUT #2

Table 4-6. Main Parachute Data - 85 Series Tests

1	2a	2b	3	4		5		6		7	
Test	Stage	Para-chute	t_{MCLS} or t_{dis}	Δt PMF to MCLS		Δt MCLS to Disreef		q_{PMF}		q_{MCLS} or $q_{Disreef}$	
85-3				Pred.	Act.	Pred.	Act.	Pred.	Act.	Pred.	Act.
Con't.	F_o	+Y	105.37	-	-	10.6	10.53	-	-	4.1	4.5
		-Y	105.40	-	-	10.6	10.34	-	-	4.1	4.5
		+Z	105.58	-	-	10.6	10.61	-	-	4.1	4.5
85-4	F_{R_1}	+Y	98.34	1.90	1.89	-	-	66.6	65.1	84.9	77.1
		-Y	98.34	1.90	1.89	-	-	66.6	65.1	84.9	77.1
		+Z	98.37	1.90	1.92	-	-	66.6	65.1	84.9	77.1
	F_{R_2}	+Y	104.31	-	-	6.4	5.97	-	-	16.3	15.0
		-Y	104.17	-	-	6.4	5.83	-	-	16.3	15.5
		+Z	104.10	-	-	6.4	5.73	-	-	16.3	15.7
	F_o	+Y	108.52	-	-	10.6	10.18	-	-	4.3	4.20
		-Y	108.26	-	-	10.6	9.92	-	-	4.3	4.30
		+Z	108.34	-	-	10.6	9.97	-	-	4.3	4.30
85-5	F_{R_1}	+Y	86.80	1.90	1.99	-	-	64.1	63.5	80.0	74.5
		-Y	86.82	1.90	2.01	-	-	64.1	63.5	80.0	74.5
		+Z	86.89	1.90	2.08	-	-	64.1	63.5	80.0	74.5
	F_{R_2}	+Y	92.84	-	-	6.4	6.04	-	-	16.8	15.0
		-Y	92.96	-	-	6.4	6.14	-	-	16.8	14.2
		+Z	93.07	-	-	6.4	6.18	-	-	16.8	13.9
	F_o	+Y	97.20	-	-	10.6	10.4	-	-	4.1	4.2
		-Y	97.25	-	-	10.6	10.43	-	-	4.1	4.2
		+Z	97.32	-	-	10.6	10.43	-	-	4.1	4.1
85-6	F_{R_1}	+Y	4.73	1.8	1.73	-	-	80.2	92.3	78.8	88.9
		-Y	4.80	1.8	1.80	-	-	80.2	92.3	78.8	88.8
		+Z	4.69	1.8	1.69	-	-	80.2	92.3	78.8	89.0

Δ ~ Very Poor Results (Questionable)

FOLD-OUT
#1

Peak Loads				12	13	14	15	16
Actual				Drag Area				$q_{Disreef}$ (Calculated)
8 Pred.	9 Link A	10 Link B	11 Parachute (ave.)	$(C_DS)_n$ Pred.	$(C_DS)_n$ Link A	Actual Link B	C_DS (ave.)	
			(9 + 10)/2				(13 + 14)/2	
9,800	-	-	-	4,200	-	-	-	
-	-	-	-	4,200	Δ	Δ	-	
-	-	-	-	4,200	-	-	-	
11,900	11,470	11,870	11,670	265	300	300	300	-
-	10,960	11,210	11,085	-	290	300	295	-
10,227	-	10,570	10,570	238	-	280	280	-
10,860	8,820	9,180	9,000	1,080	950	950	950	15.38
-	8,950	9,500	9,225	-	950	950	950	15.52
10,526	-	9,020	9,020	1,080	-	1,000	1,000	15.59
10,425	6,180	6,560	6,370	4,200	4,400	4,500	4,450	4.63
-	7,540	7,530	7,535	4,200	4,100	4,000	4,050	4.66
-	-	7,560	7,560	4,200	-	4,500	4,500	4.65
10,315	12,744	12,751	12,748	265	300	290	295	-
-	9,639	9,597	9,618	238	245	245	245	-
8,400	10,787	10,519	10,653	265	310	300	305	-
10,760	9,890	9,728	9,809	1,080	1,000	960	960	14.94
-	6,056	5,999	6,028	972	730	730	730	14.87
10,450	8,180	8,046	8,113	1,080	1,050	1,030	1,040	14.78
9,800	8,353	8,181	8,267	4,200	3,500	3,300	3,400	4.68
-	5,021	5,059	5,040	4,200	3,300	3,300	3,300	4.67
-	7,730	7,489	7,610	4,200	3,200	3,100	3,150	4.66
9,765	12,840	12,860	12,850	265	400	370	385	
-	-	-	-	238	-	-	-	
7,803	12,050	14,690	13,475	265	270	350	310	

FOLD-OUT #2

Table 4-6. Main Parachute Data - 85 Series Tests (Continued)

1	2a	2b	3	4		5		6		7	
Test	Stage	Parachute	t_{MCLS} or t_{dis}	Δt PMF to MCLS		Δt MCLS to Disreef		q_{PMF}		q_{MCLS} or $q_{Disreef}$	
85-6				Pred.	Act.	Pred.	Act.	Pred.	Act.	Pred.	Act.
Con't.	F_{R_2}	+Y	10.93	-	-	6.4	6.20	-	-	15.2	14.5
		-Y	11.00	-	-	6.4	6.20	-	-	15.2	14.3
		+Z	11.07	-	-	6.4	6.38	-	-	15.2	14.0
	F_o	+Y	15.16	-	-	10.6	10.43	-	-	4.1	3.8
		-Y	15.44	-	-	10.6	10.64	-	-	4.1	3.70
		+Z	15.24	-	-	10.6	10.55	-	-	4.1	3.80
85-7	F_{R_1}	+Y	-	-	-	-	-	-	-	-	-
		-Y	93.56	1.90	1.97	-	-	64.1	63.3	81.9	76.2
		+Z	93.72	1.90	2.13	-	-	64.1	63.3	81.9	76.4
	F_{R_2}	+Y	-	-	-	-	-	-	-	-	-
		-Y	99.71	-	-	6.4	6.15	-	-	23.7	24.5
		+Z	99.72	-	-	6.4	6.00	-	-	23.7	24.5
	F_o	+Y	-	-	-	-	-	-	-	-	-
		-Y	103.97	-	-	10.6	10.41	-	-	6.3	7.1
		+Z	104.02	-	-	10.6	10.30	-	-	6.3	7.0

Fold-Out #1

Peak Loads				12	13	14	15	16
Actual				Drag Area				$q_{Disreef}$ (Calculated)
8 Pred.	9 Link A	10 Link B	11 Parachute (ave.)	$(C_D S)_n$ Pred.	$(C_D S)_n$ Link A	Actual Link B	$C_D S$ (ave.)	
			(9 + 10)/2				(13 +14)/2	
10,360	11,100	11,220	11,160	1,080	1,600	1,600	1,600	
-	-	-	-	972	-	-	-	
9,975	8,200	10,070	9,500	1,080	1,000	1,300	1,150	
9,820	10,020	9,900	9,960	4,200	8,800	8,500	8,650	
-	-	-	-	4,200	-	-	-	
-	6,000	7,270	6,720	4,200	5,600	7,000	6,300	
-	-	-	-	-	-	-	-	
15,260	14,592	12,601	13,597	285	280	240	260	-
-	9,902	10,022	9,962	257	200	200	200	-
-	-	-	-	-	-	-	-	
16,665	17,561	15,297	16,429	1,080	1,050	920	985	26.71
-	9,587	9,471	9,529	972	670	670	670	26.71
-	-	-	-	-	-	-	-	
14,780	15,009	12,789	13,900	4,200	4,300	3,700	4,000	7.84
-	10,284	10,447	10,366	4,200	4,200	4,200	4,200	7.83

FOLD-OUT #2

Table 4-6. Main Parachute Data - 85 Series Tests (Continued) dynamic pressure calculated using calculated drag areas. For each test where the calculated drag area is high, the resulting calculated dynamic pressure is lower than the measured value; the reverse is true where the calculated drag area is low.

A calculated dynamic pressure at first stage disreef, using pretest drag areas (Column 7 predicted) and using post-test calculated drag areas (Column 16), is available for each test. These dynamic pressure drag area points, for each test are plotted in Figure 4-22. If first stage disreef dynamic pressure is assumed to vary with parachute drag area as indicated by the resulting plots, the drag area required to obtain the measured dynamic pressure (Column 7 actual) may be determined. This drag area should be a good approximation of that obtained during each test. As shown in Figure 4-22, the drag area required to obtain the dynamic pressure measured during Tests 85-1, 85-4, 85-5 and 85-7 is 884, 864, 844 and 530-ft^2, respectively. The average drag area for the three-parachute tests is 864 or 5 percent higher than the latest three-parachute drag area (827-ft^2) being used to calculate design loads. For the one two-parachute test, the drag area is 530-ft^2; this is two percent lower than the 542-ft^2 used to calculate design loads.

All dynamic pressures measured at the time of the lead parachute second-stage disreef compare well with predicted dynamic pressures when corrected for reefing cutter disreef time. Figure 4-23 presents the second stage drag area required to obtain the second stage disreef dynamic pressure measured during each test. Figure 4-23 was constructed following the same procedure as was described above for the first stage. The average drag area for the three parachute tests is 3047-ft^2 or 97 percent of the predicted drag area of 3132-ft^2. For Test 85-7 (two parachute test) the drag area (1860-ft^2) is 91 percent of predicted drag area.

Based on the above, it is seen that the first and second stage drag areas obtained during the 85 Series tests are in close agreement with the latest drag areas used to calculate design loads.

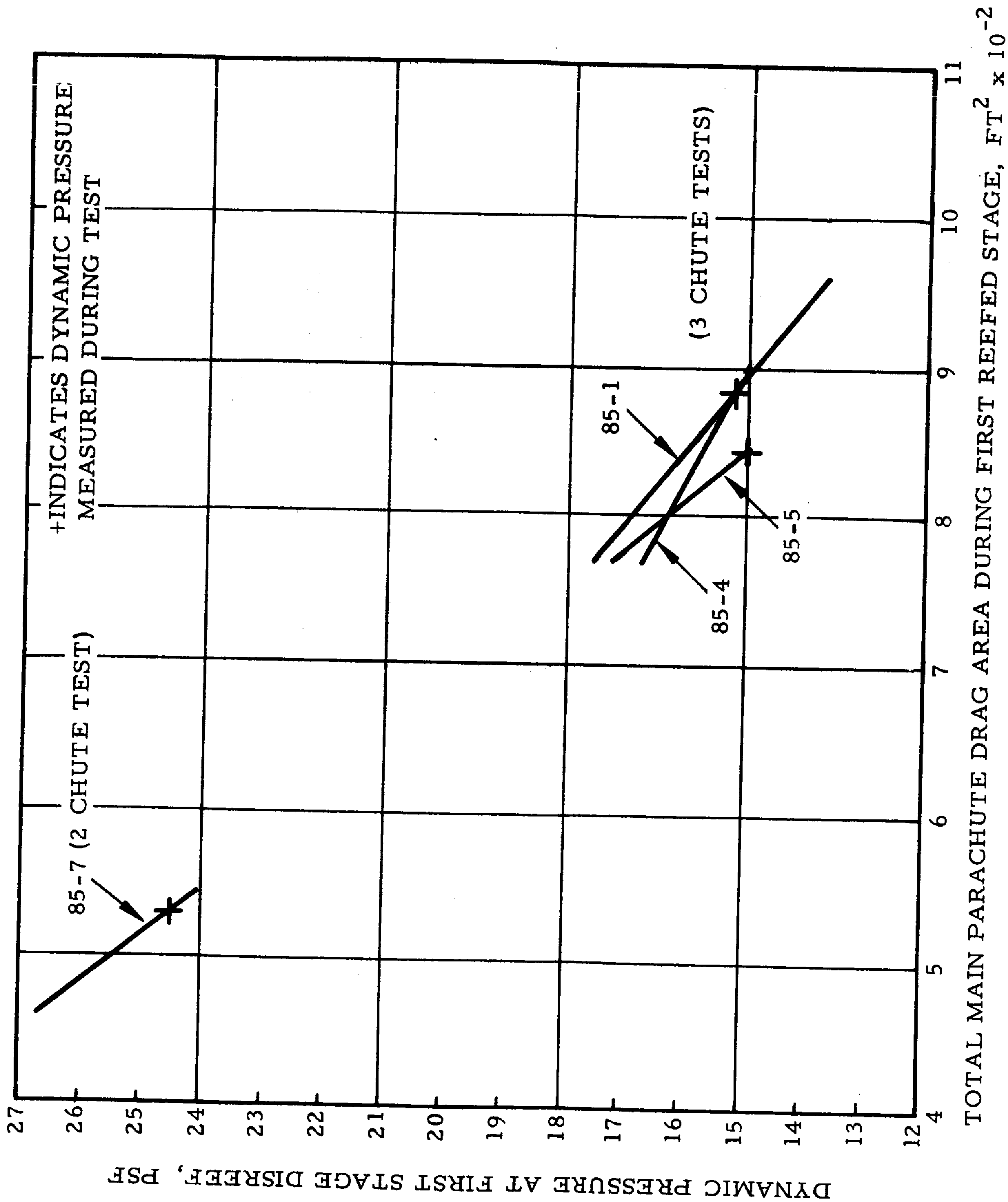

Figure 4-22. Disreef Dynamic Pressure vs. Drag Area - First Stage

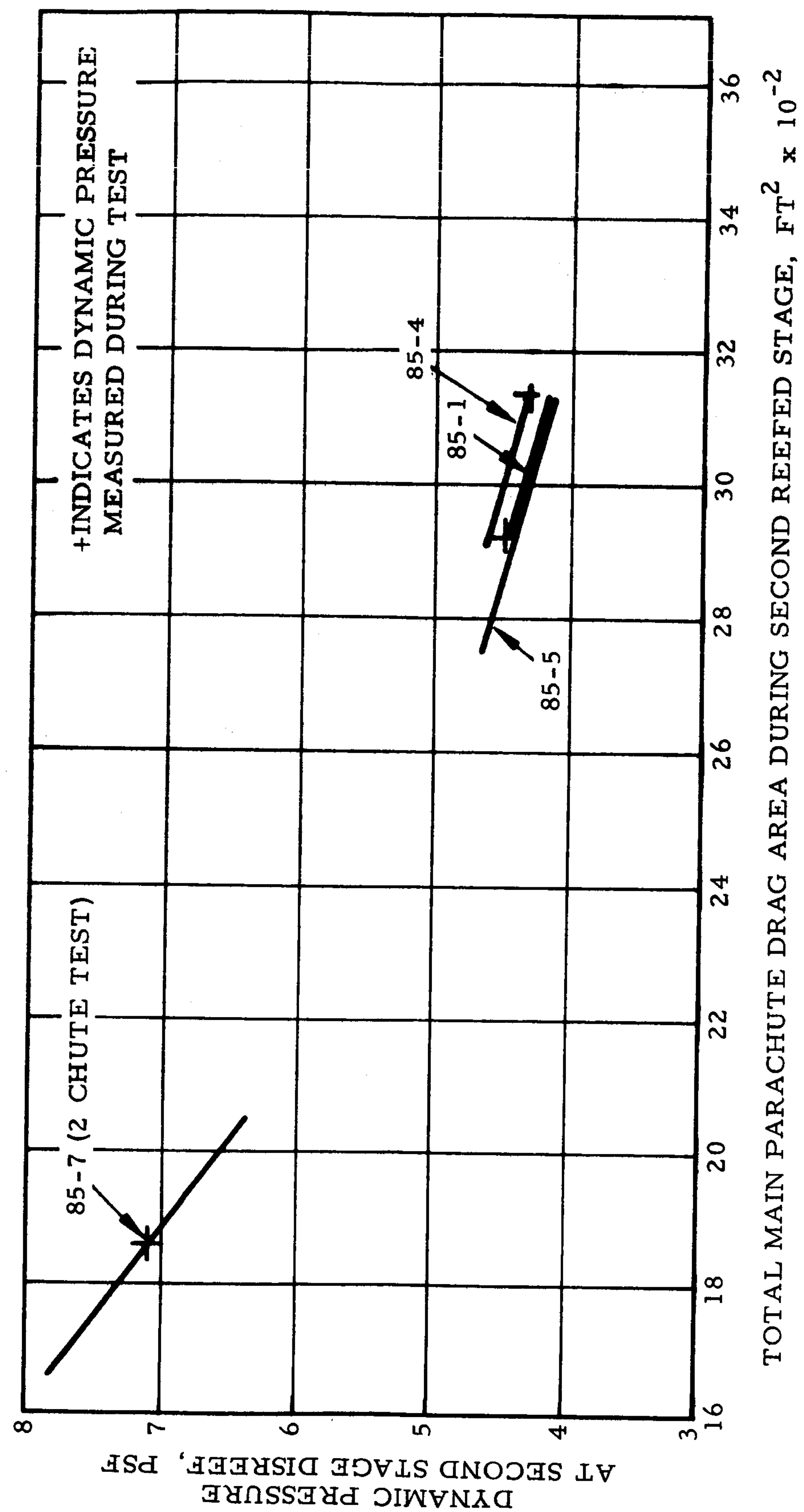

Figure 4-23. Disreef Dynamic Pressure vs. Drag Area - Second Stage

As was noted above, complete loads data were obtained only on Tests 85-1, 85-4, 85-5 and 85-7. The data that was obtained from Tests 85-1, 85-2, 85-3 and 85-6 was of poor quality. Basic evidence of this was the erroneous shape and magnitude of the drag area time plots obtained from the data. Tests 85-4, 85-5 and 85-7 were conducted using redesigned instrumentation. Measured and predicted loads for these latter tests are shown in Table 4-7.

All predicted loads in Table 4-7 have been corrected for dynamic pressure. In addition, the first reefed stage (F_{R_1}) predicted loads have been adjusted to a lead parachute first stage drag area of 285. All F_{R_1} predicted loads include a five percent dynamic factor.

Review of Table 4-7 shows that there is good correlation between predicted and measured F_{R_1} loads for Tests 85-4 and 85-7. The measured load for Test 85-5 is high. The measured second stage peak loads (F_{R_2}) are lower than the predicted loads for all tests. This indicates that second stage reefed drag area may be a small percentage less than assumed or that the 1000 ft^2 fill rate being used is a little high. For full open peak loads (F_o), all measured loads are lower than predicted. In all cases, there was only a small time difference between parachutes at second stage disreef, i.e., close to simultaneous disreef. It is believed that the technique for computing full open loads is conservative when disreef is essentially simultaneous.

Table 4-7. Main Parachute Measured and Predicted Loads

Stage	Test 85-4		Test 85-5		Test 85-7	
	Predicted	Measured	Predicted	Measured	Predicted	Measured
First Reefed (F_{R_1})	11,900	11,670	11,060	12,750	13,690	13,600
Second Reefed (F_{R_2})	10,500	9,225	10,000	9,810	16,930	16,429
Full Open (F_o)	10,420	7,560	10,000	8,270	16,190	13,900

SECTION 5.0

RELIABILITY EVALUATION

The Reliability Evaluation of the Apollo 85-Series Qualification Tests is presented in this section. (The numerical reliability assessment will be submitted in NVR-6249.) The evaluation consists of a reliability analysis of the tests, analysis of subsystem performance followed by a reliability summary.

5.1 RELIABILITY ANALYSIS OF THE TESTS

Objectives of the seven qualification tests were reviewed considering test conditions, quantities, and planning. A simplified matrix (Table 5-1) was developed indicating tests, their differences, and accomplishment of objectives.

Pertinent observations include:

a. All test objectives were accomplished.

b. Significant reliability objectives were accomplished on all seven tests.

c. The functioning of the recovery system with a single drogue parachute was successfully demonstrated (four out of six tests utilized single drogues).

d. The capability of the Parachute Subsystem to achieve normal vehicle recovery on the optional drogue by-pass situation was successfully demonstrated.

e. The capability of the Parachute Subsystem to achieve normal vehicle recovery with only one drogue and two main parachutes operating was successfully demonstrated.

f. The pilot riser sleeve corrective action was successfully demonstrated.

Table 5-1. Test Summary Matrix

Test No.	Date	Test Description	Test Objectives Accomplished: Evaluate System Performance	Evaluate Drogue Parachute Performance	Determine Drogue/ Boilerplate Stability	Verify Reefed Inflation Load-Sharing	Verify Disreefed Inflation Load-Sharing	Verify Forward Heat Shield Separation	Verify Main Parachute Two-Stage Reefing
85-1	4-4-68	Two Drogues Three Main Parachutes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
85-3	4-24-68	Single Drogue Three Main Parachutes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
85-2	5-1-68	Pad Abort Increased Capability Two Drogues Three Main Parachutes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
85-6	5-14-68	Pad Abort No Drogues Three Main Parachutes	Yes	Not Required	Not Required	Yes	Yes	Not Required	Yes
85-5	6-6-68	High Altitude Abort Single Drogue Three Main Parachutes	Yes	Yes	Yes	Yes	Yes	Not Required	Yes
85-4	6-14-68	Overweight Test Vehicle Single Drogue Three Main Parachutes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 5-1. Test Summary Matrix - Continued

Test No.	Date	Test Description	Test Objectives Accomplished						
			Evaluate System Performance	Evaluate Drogue Parachute Performance	Determine Drogue/ Boilerplate Stability	Verify Reefed Inflation Load-Sharing	Verify Disreefed Inflation Load-Sharing	Verify Forward HeatShield Separation	Verify Main Parachute Two-Stage Reefing
85-7	7-3-68	High Altitude Abort Single Drogue Two Main Parachutes	Yes	Yes	Yes	Yes	Yes	Not Required	Yes

5.2 ANALYSIS OF SUBSYSTEM PERFORMANCE

A reliability analysis of each of the major subsystems is described in the following paragraphs.

5.2.1 Forward Heat Shield Mortar Assembly

Verification of Forward Heat Shield separation was a test objective of four of the seven drop tests. High reliability was indicated as no malfunctions or problems were encountered.

5.2.2 Drogue Parachute Mortar Assembly

Drogue parachute mortar assembly operation was demonstrated in six of the seven qualification drops. In four of these tests, only one drogue was utilized. In all cases the drogue parachute deployed and inflated successfully with properly programmed conditions for subsequent events to occur. The demonstrated single drogue success greatly enhances the probability of successful recovery of spacecraft in the event of single drogue failure in the two drogue system.

In Test 85-3 (first single drogue test in Qualification Series), there was moderate abrasion, and some of the wires in each of the four drogue metal riser cables were broken in the section adjacent to the 1.5 inch radius of the riser attach fitting (flowerpot). An engineering evaluation was performed to determine the cause of this cable condition. The basic cause was attributed to boilerplate oscillations while descending on a single drogue causing cable abrasion. Breakage of the wire under load was the result of the combined effects of:

a. Wire deformation

b. Wires passing over the gap-step in the flowerpot fitting.

c. Wires sliding over adjacent wires.

d. Flexure of the wires as a result of flowerpot oscillations.

North American Rockwell investigated this problem using various configurations and protective coatings. Cable tension load tests were conducted with cable coatings of lead tape, polyurethane and copper. The tests resulted in an improved and adequate capability with lead tape.

Action taken was the wrapping of each cable with 3M Scotch lead tape. Three subsequent qualification drop tests (all single drogue) verified the adequacy of the corrective action. In all cases the lead tape sufficiently protected the drogue riser cables.

5.2.3 Pilot Parachute Mortar Assembly

The pilot parachute mortar assembly (three each for the first six tests and two for the seventh test) operated successfully on all seven qualification drops. Post-drop assessment revealed that the parachute riser sleeve was torn loose at the lower end and bunched toward the confluence keeper. This was considered by NASA to be a significant problem for the sleeve could possibly slip up over the keeper and a portion of the suspension lines above the confluence point and cause restriction of chute inflation. An engineering evaluation resulted in a design change to lengthen the riser sleeve and incorporate a heavier stirrup with additional sewing of the stirrup to the sleeve. Verification of this corrective action was accomplished during the final four qualification drops in which the problem did not reoccur. Significantly, Test 85-4 was with an overweight vehicle and Test 85-7 utilized only two main chutes.

5.2.4 Main Parachute Pack Assembly

The deployment of three main parachutes was successfully accomplished in each of the first six tests, and two main parachutes were deployed in the seventh test. In each test the parachutes functioned as required. Typical deployment bag and chute damage was recorded, considered normal and attributed to packing and impact damage.

In Test 85-3 one suspension line broke approximately twelve feet below the skirt on one main parachute. Film coverage indicated that the break occurred during deployment. A failure mode analysis of such an anomaly indicates possible significant effect under high "q" conditions. The loose suspension line might wrap around other lines or the canopy, preventing inflation or disreef of a parachute or causing damage to the canopy. The failure mode probability is considered extremely remote.

In Tests 85-5 and 85-6, on one deployment bag, the master loop broke and the break cord remained intact. The master loop normally has about three times the tensile strength of the break cord. Breaking of the master loop was attributed to possible fraying as a result of packing. This type of failure apparently does not restrict pack opening and therefore will not constrain mission success. It is recommended, however, that equipment condition and packing procedures be further reviewed to eliminate this failure mode.

In Test 85-6, in another parachute assembly, the master loop pulled out of the web loop on the bag. Though this did not cause any mission problems, it was considered a significant failure that could possibly restrict pack opening. An analysis of the problem revealed a condition of blind sewing in which there was no positive way of ascertaining that the master loop was properly attached to the loop of webbing. Manufacturing, assembly and inspection procedures were changed to correct the problem. Three subsequent qualification drops verified the corrective action.

A significant reliability objective of the Apollo qualification drops was the final descent rate of the vehicle on the main parachutes. A summary of test requirements and actual recorded data is as follows:

Test No.	Requirements* (ft/sec)	Actual Mean (ft/sec)
85-1	38	31.7
85-3	38	31.9
85-2	38	29.3
85-6	38	34.2
85-5	38	32.8
85-4	38	28.4
85-7	38**	34.7

*Customer requirement based on the deployment of two main parachutes.
**Two main parachutes used on this test only. Previous six tests deployed three main parachutes.

The parachute subsystem met the descent rate requirements on all tests with Test 85-7 indicating an excellent safety margin.

The allowable descent rate when using three main parachutes should be established and maintained for all subsequent drop tests.

5.2.5 Main Parachute Riser Assembly

Three main parachute riser assemblies were used in each of the first six qualification drops and two assemblies were used in the seventh qualification drop. All performed successfully. The risers were instrumented on all drop tests.

In Test 85-1, a bushing was not inserted through the clevis hole (on one side). Consequently, the bushing was cocked out of alignment. The full load on that side of the clevis was impressed upon the washer instead of the bushing with resultant deformation of the clevis assembly. An engineering evaluation resulted in a change directive to include a check point to insure proper bushing insertion during final assembly of the clevis.

On the qualification drop tests where a single drogue parachute was employed, vehicle roll caused the main chute risers to wrap around each other. The extent of wrapping was from partial to the full length of the metal risers. There was no apparent adverse effect on metal riser strength or upon functioning of the main parachutes.

It is recommended that maximum roll rates anticipated on spacecraft recovery be thoroughly verified and compared with the roll rates experienced on the qualification drop tests. The possibility of complete wrap-up of main parachutes may exist.

5.3 SUMMARY

The reliability of the earth landing system is considered satisfactory. The seven qualification tests provided considerable confidence that the system will successfully recover a spacecraft within the predicted spectrum of flight trajectory.

SECTION 6.0

CONCLUSIONS

All seven qualification aerial drop tests of the Block II Increased Capability Parachute Subsystem provided satisfactory results, with all specified performance requirements achieved and test objectives fulfilled. On the basis of Parachute Subsystem performance during the Series 85 Qualification Drop Tests, along with successful laboratory qualification of certain components and assemblies, and appropriate consideration for components and assemblies which are identical or similar to earlier Block II design; Northrop Ventura considers the Block II Increased Capability Parachute Subsystem qualified in accordance with the requirements set forth by NR Specification ME 623-0006.

6.1 CONFIGURATION VALIDITY

A spacecraft design configuration for the Parachute Subsystem was achieved on the first drop test, and it remained unchanged throughout the qualification drop test program; the only exception being minor improvement modifications to the pilot parachute fabric riser. These modifications (described in Paragraph 2.3) were accomplished to strengthen the sleeve over the fabric riser to prevent it from breaking loose at the lower end and gathering toward the keeper. This was not considered a major design change, inasmuch as system form, fit, or function was not affected. It is concluded that the Series 85 Tests constituted a satisfactory demonstration of the Apollo Block II Increased Capability Parachute Subsystem with regard to the validity of test specimen configuration and with respect to the Work Statement of the Purchase Order.

As discussed in Section 2.0, the configuration tested during this test series is identical to spacecraft design with the exception of the drogue and main parachute steel risers which were instrumented for loads acquisition. The configuration of the system tested can be compared to the S/C 101 configuration which is considered to be the qualified Block II Increased Capability spacecraft production design. It is further concluded that the Series 85 tests, along with prior development test results, provides a valid basis for acceptance of the Block II Increased Capability Parachute Subsystem configuration with respect to hardware tested.

6.2 PARACHUTE PACKING AND INSTALLATION

Stabilization of the main parachute pack configuration as a production design was illustrated by the successful packing of twenty (20) parachute test specimens. Uneventful extraction and deployment of the main parachutes from the deployment bag without major damage to either the parachute or deployment bag and without extraction delays, also verifies the final design from the standpoint of deployment performance.

Post-test inspection of all parachute test specimens indicates that the packing procedures have been optimized and are satisfactory for use with the Block II Increased Capability Parachute Subsystem. Only minor tolerable damage was discovered and this was primarily due to the rigorously controlled pressure packing process. This was considered typical random packing damage and its frequency of occurrence was low.

Installation and rigging of Parachute Subsystem components into the respective bays of the forward compartment of Boilerplate-6C was successfully accomplished throughout all seven tests without incident, which indicates that the Block II Increased Capability installation procedures are of spacecraft design standards with no improvements required.

6.3 FORWARD HEAT SHIELD AUGMENTATION

The forward heat shield was utilized in four of the seven drop tests and was successfully jettisoned during each test prior to drogue parachute deployment.

The R8130-5 Forward Heat Shield Mortar Assembly performed its design function through the successful deployment of the forward heat shield parachute. This parachute augmented the separation of the jettisoned forward heat shield by retarding its downward velocity.

The forward heat separation augmentation system is considered fully qualified in accordance with the requirements specified in ME 623-0005 on the basis of its performance during the aerial drop tests and during the laboratory qualification tests.

6.4 RATE OF DESCENT

Utilizing a boilerplate vehicle at specification weight and three operating main parachutes, the maximum and minimum rates of descent were 35.4 and 28.0 ft/sec, respectively, with the average mean value being 31.4 ft/sec. The mean rate of descent for the two main parachute design case, Drop Test 85-7, was 34.7 ft/sec, which was well within the design limit of 38 ft/sec.

In addition, a mean rate of descent of 28.4 ft/sec was demonstrated with an overweight test vehicle (final descent weight of approximately 13,420 pounds). The Parachute Subsystem met the specified rate of descent requirements on all seven drop tests. For additional information on final descent rates, refer to Paragraph 4.6.

SECTION 7.0

REFERENCES

NOTE: Both cited references and documents of overall general interest are included in this list of references. Because of the great amount of documentation related to this program, the referenced documents and others have been grouped by source and by catgory from each source.

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6. NR Specification MC 623-0005, "Mortar Assembly, Forward Heat Shield Augmentation."

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33. NVR-6173, "Thermal Analysis Apollo Earth Landing System, Block II Increased Capability Program," March 1968.

Packing and Rigging Instructions

34. NVR-6012C, "Drogue Parachute, Inspection and Packing Instructions (Increased Capability)."

35. NVR-6013B, "Drogue Parachute Mortar Assembly Instructions."

36. NVR-6015B, "Main Parachute, Inspection and Packing Instructions (Increased Capability)."

37. NVR-6019A, "Forward Heat Shield Parachute Mortar Assembly Instructions."

38. NVR-6020A, "Forward Heat Shield Parachute, Inspection and Packing Instructions."

39. NVR-3859, "Main Parachute Assembly Procedures."

40. NVR-6044, "Pilot Parachute, Inspection and Packing Instructions."

41. NVR-6045, "Pilot Parachute Mortar Assembly Instructions."

42. NVR-6050B, "Boilerplate Test Vehicle, Installation and Rigging Instructions (Increased Capability)," June 1968.

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43. NVR-5091D, "General Test Plan, Apollo Block II ELS, Increased Capability Program," March 1968.

44. NVR-3876D, "Field Test Operations Plan, Apollo Block II ELS, Increased Capability Program," March 1968.

45. DFTP 85-1A, with FCN's 85-1A-1, -2, -3, -4, and -5, "Detailed Field Test Plan for Apollo Block II Parachute Subsystem, Qualification Drop Test 85-1," 15 March 1968.

46. DFTP 85-2B, with FCN's 85-2B-1, -2 and -3, "Detailed Field Test Plan for Apollo Block II Parachute Subsystem, Qualification Drop Test 85-2," 12 April 1968.

47. DFTP 85-3B, with FCN's 85-3B-1, -2, -3, -4, and -5, "Detailed Field Test Plan for Apollo Block II Parachute Subsystem, Qualification Drop Test 85-3," 4 April 1968.

48. DFTP 85-4A, with FCN 85-4A-1, "Detailed Field Test Plan for Apollo Block II Parachute Subsystem, Qualification Drop Test 85-4," 24 May 1968.

49. DFTP 85-5B, with FCN 85-5B-1, "Detailed Field Test Plan for Apollo Block II Parachute Subsystem, Qualification Drop Test 85-5," 24 May 1968.

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End Item Detail Specifications

52. SS-00003B, "Performance/Design Requirements, Apollo Block II Parachute Subsystem Increased Capability," 14 March 1968.

53. CP-00700C, "Performance/Design Requirements, Drogue Parachute Mortar Assembly, for Block II," 17 April 1968.

54. CP-00501D, "Performance/Design and Product Configuration Requirements, Pilot Parachute Mortar Assembly for Apollo Block II Earth Landing System," 7 March 1968.

55. CP-00702B, "Performance/Design Requirements, Pack Assembly, Main Parachute, for Apollo Block II Parachute Subsystem," 22 February 1968.

56. CP-00503C, "Performance/Design and Product Configuration Requirements, Riser Assembly, Main Parachute, for Apollo Block II Earth Landing System," 3 January 1968.

57. CP-00504C, "Performance/Design and Product Configuration Requirements, Retention Assembly, for Apollo Block II Earth Landing System," 3 January 1968.

58. CP-00505C, "Performance/Design and Product Configuration Requirements, Drogue Pressure Cartridge for Apollo Block II Earth Landing System," 3 January 1968.

59. CP-00506C, "Performance/Design and Product Configuration Requirements, Pilot Pressure Cartridge for Apollo Block II Earth Landing System," 3 January 1968.

60. CP-00701C, "Performance/Design and Product Configuration Requirements, Forward Heat Shield Separation Augmentation Mortar Assembly for Apollo Block II Earth Landing System," 23 February 1968.

Flight Readiness Review Data Packages

61. NVR-6180C, "Flight Readiness Review Data Package for Apollo, Drop Test 85-1," 29 March 1968.

62. NVR-6216A, "Flight Readiness Review Data Package for Apollo, Drop Test 85-2," 2 May 1968.

63. NVR-6187B, "Flight Readiness Review Data Package for Apollo, Drop Test 85-3," 24 April 1968.

64. NVR-6236, "Flight Readiness Review Data Package for Apollo, Drop Test 85-4," 7 June 1968.

65. NVR-6220A, "Flight Readiness Review Data Package for Apollo, Drop Test 85-5," 24 May 1968.

66. NVR-6229, "Flight Readiness Review Data Package for Apollo, Drop Test 85-6," 2 May 1968.

67. NVR-6248, "Flight Readiness Review Data Package for Apollo, Drop Test 85-7," 17 June 1968.